Wolfe & Wiersema

Comparison of Various Floor Systems in Reinforced Concrete

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COMPARISON OF VARIOUS FLOOR SYSTEMS IN REINFORCED CONCRETE

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

William Sidney Wolfe and Harry Anthony Wiersema

ENTITLED Comparison of Various Floor Systems in

Reinforced Concrete

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Architectucal Engineering

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I. Introduction.

1. Purpose and Methods.

In recent years a large number of different systems of reinforced concrete floor construction have sprung up in this country, some of which have attained wide commercial use. Information concerning these various systems is, however, scattered and inadequate. Many of the systems differ from each other only in the type of reinforcement which they employ; others in the method of placing the reinforcement; while some employ entirely distinct methods of construction. It is the purpose of this thesis to present information concerning all of these systems in such a manner as to give an adequate basis for comparison and classification.

In this investigation the important points concerning each system are arranged in the following order.

1. Commercial Use
2. Patents and Manufacturers
3. Loads, Spans, and Materials
4. Reinforcement
5. Design
6. Centering
7. Examples of Buildings
8. Tests and Failures

Letters were sent to all the manufacturers and contractors advertising in the more important engineering periodicals, and

the literature received in reply was investigated. On the next page is given a list of the companies whose literature was reviewed.

2. Manufacturers and Contractors From Whom Literature was Received.

1. American Concrete Steel Co. -- Newark, N. J.
2. American Steel and Wire Co. -- Chicago.
3. American System of Reinforcing. -- Chicago.
4. Baltimore Siegwart Beam Co. -- Baltimore.
5. Barton Spider Web Company -- Chicago.
6. Berger Manufacturing Co. -- Canton, Ohio.
7. Brown Hoisting Machinery Company -- Chicago.
8. Clinton Wire Cloth Company -- Clinton, Mass.
9. Concrete Steel Company -- New York.
10. Concrete Steel Products Company -- Chicago.
11. Consolidated Expanded Metal Co. -- Pittsburg.
12. Corrugated Bar Company -- Buffalo.
13. General Fireproofing Company -- Youngstown, Ohio.
14. Hennebique Construction Company -- New York.
15. Interstate Iron and Steel Co. -- Chicago.
16. International Fence and Fireproofing Co. -- Columbus.
17. Jones and Laughlin -- Pittsburg.
18. National Fireproofing Company -- Chicago.
19. Nolan, J. S. & Company -- Chicago.
20. Northwestern Expanded Metal Co. -- Chicago.
21. Pittsburg Steel Products Company -- Pittsburg.
22. Standard Concrete Steel Co.-- New York.
23. Trussed Concrete Steel Company -- Detroit.
24. Turner, C. A. P. -- Minneapolis.
25. Unit Construction Company -- St. Louis.

26. Vaughan Company -- Detroit.

27. White Construction Company -- New York.

28. Wight, W. N. and Company -- New York.

29. Wilson System of Construction-- Boston.

3. Bibliography

1. Adams and Mathews -- Reinforced Concrete Construction
2. Atlas Portland Cement Company -- Factory Construction
3. Beton -- Kalendar
4. Brayton Standards
5. Buel and Hill -- Reinforced Concrete
6. Colby -- Reinforced Concrete in Europe
7. Expanded Metal System
8. Freitag -- Architectural Engineering
9. Freitag -- Fireproofing of Steel Buildings
10. Handbuch für Beton Eisen Bau
11. Heidenreich -- Pocket Book for Reinforced Concrete
12. Kahn System Standards
13. Lavergne -- Etude des Divers Systimes de Construction en Ciment Arme'
14. Kidder -- Handbook
15. Kidder -- Masonry Construction
16. Marsh and Dunn -- Manual of Reinforced Concrete
17. Radford -- Cyclopedia of Construction
18. Reid -- Concrete and Reinforced Concrete Construction
19. Richey -- Ready Reference
20. Sutcliff -- Concrete--Nature and Uses
21. Taylor and Thompson -- Concrete
22. Trautwine -- Concrete
23. Turneaure and Mauer -- Reinforced Concrete
24. Turner -- Concrete Steel Construction
25. Twelvetrees -- Concrete Steel
26. Twelvetrees -- Concrete Steel Buildings.

II. Girderless Floors

Among the various types of floor systems in use today, the girderless floor offers the greatest possibilities. It consists primarily of a flat concrete slab resting directly on the column tops, all projecting beams and girders being eliminated, and the material thus saved being used to increase the thickness of the slab.

Many advantages are gained by this method, the more important being a reduction in story height, increase in lighting area, and simplicity of centering. It is also advantageous where a uniform flat ceiling is desired in special cases; and also in case of fire, as it allows full sweep to a stream of water along the ceiling. It is especially well adapted to large floor areas, as in factory buildings, and the contractors claim that it is more economical for heavy loads than for light ones.

The analysis of stresses in girderless floors has not yet been placed on a substantial basis. The analogy is not strong enough to warrant the use of the theory of the circular plate, nor can the slab be properly designed as a plain cantilever. It has been customary, therefore, to base all designs on actual tests. These show that failures generally occur directly around the column top, due to diagonal tension. Heavy reinforcement is therefore required over columns.

The systems considered here are the Akme, the Spider Web, the Cantilever Flat Slab, the Corr Plate, and the Turner system.

1. Akme System

Plate I & II.

Girderless floors may be divided into two classes, those having four way and those having two way reinforcement. The Akme System was the first of the two way class to be used in actual building construction; its distinctive feature is the reinforcement of a wide strip, a, (see Plates I & II) extending over and parallel to the rows of columns, so that they will act as wide flat beams; and the reinforcement of the small square, b, as a common slab. In some cases the portion b is made thinner than the rest of the slab, thus giving a panel effect, and making the beam construction more apparent.

This system was patented by Mr. Condron of Chicago about 1908, and a royalty is retained for its use.

Spans used in this system vary from 14 x 14 ft. to 24 x 24 ft. and are designed for loads of from 100# to 225# per sq. ft., which loads they have successfully withstood with slight deflection in several tests.

As a rule some type of deformed or corrugated bars are used, which are bent up to the top of the slab, over the column, in order to take up the negative bending moment. The engineers of the company design this floor according to their own formula, giving dimensions of reinforcement for various spans and loads. It is seen that this system can be analyzed as four wide beams over the columns, supporting a central slab.

Ordinary wood centering is used except for the capitals, for which sheet metal forms are used. This system has been used in many buildings in the Central West, among which are the following: Wagner Electric Mfg. Co., St. Louis, Mo.; Warehouse of Peck and Hills Furniture Co., Chicago; Monogram Building, St. Louis, Mo.; and the Studebaker Automobile Co. Building, Chicago.

The following table of tests is given by the company.

Building	Column Spacing	Diagonal Span	Slab Thickness Max.	Slab Thickness Min.	Slab Thickness Ave.	Live-load #	Test Load #/sq'	Test Load Area sq '	Test Load Total load	Test Load Max. dif."
Studebaker	24'-0"x 23'-9"	33'9"	12 "	6 "	8.6"	100	300	570	171000	0.34
Peck & Hills	14'-8"x 14'-0"	20'3"	7.5"	4 "	5.7"	150	280	196	54800	.06
Oak Pk. W H	16'-10"x 15'-3"	22'8"	9 "	5.5	6.5"	150	300	256	76800	.08
Peck & Hills	16'-2"x 15'-10"	22'7"	7.5"	4 "	5.5"	100	275	256	70400	.12
Sharples	18'-0"x 17'-5"	25'0"	8 "	8 "	8. "	225	550	625	34400	.22

2. Cantilever Flat Slab

Plate III.

This system is of the four way reinforcement class, and is similar in many respects to the pioneer system of this class, the Mushroon system, differing from it mainly in the reinforcing over and between the column top and the slab. This may be readily seen by reference to Plates III and VI. It is extensively used throughout the West and Middle West.

It is patented by the Concrete Steel Products Company of Chicago, the first patents being issued in 1902.

It is adapted to long spans, and loads varying from 100 to 200 pounds per sq. ft.

For reinforcement, plain bars are used, bent over the columns as shown in the illustrations.

The company furnishes details of design for particular buildings, basing the design upon actual tests, and no definite analysis of stresses has been given.

Wood centering with sheet metal capital forms is used.

Some of the more important buildings in which this system was used are as follows:

Rike-Kumber & Co. Department Store -- Dayton, Ohio.

Deere and Company Building -- Spokane, Wash.

Sickles and Co's Warehouse -- Davenport, Iowa.

Heath and Milligan Building -- Chicago.

Deere and Webber Building -- Minneapolis.

The company reports a test on the Quaker Oats Co. Building in Cedar Rapids, Iowa, in which six panels, 20' x 20' of a 9" slab were loaded with 315# per sq. ft., superimposed load, in which it is claimed there was no deflection.

Although tests have been conducted in which the stresses in the concrete and steel in different parts of the slab were measured, it is very doubtful if a rational basis for design can be deduced from the results. It is probable, however, that the floors as designed possess ample strength.

3. Corr Plate System

Plate 1V.

This system is one of the newer forms of flat slab construction, using a two way reinforcement. As yet it has been used only to a limited extent. It was invented by the Corrugated Bar Co. of Buffalo, N. Y., and patent rights are reserved.

Spans from 15 to 25 feet, with a minimum thickness of from 5 to 14 inches and a live load of from 40 to 500 # per sq. ft. are recommended.

The reinforcement consists of corrugated bars placed as

shown in plate IV. No special form of reinforcement is used over the columns, but the bars are spaced closer. In designs furnished by the company, the allowable stresses are 18,000 # per sq. in. in the steel, and 750 # per sq. in. in the concrete.

The addition to the Ford Manufacturing Plant of the Ford Motor Co., of Detroit, Mich., was erected in this system.

4. Spider Web System

Plate V.

This system is another of the recent offshoots of the Mushroom System, using four way reinforcement, but differing from it in the reinforcement over columns. A fabricated mat of steel rods is placed over the column, as shown in Plate V. As yet it has been used but little commercially.

The inventors and promoters are the Barton Spider Web System Company of Chicago, and patents are now pending.

It is presumed that this system can be used for long spans and heavy loads, similar to other flat slab systems, although as yet experimental data is limited.

From the illustration it appears that especial attention has been given to the reinforcement for stresses over the columns. As usual, the company furnishes designs.

5. Turner Mushroom System.

Plate VI.

As has been stated, the Mushroom system was the first of all girderless floors. It has been widely used throughout the Middle

West, but has not found much favor in Chicago, on account of the strictness of the building ordinances there. It uses four way slab reinforcement, and is especially well reinforced over column tops, as may be seen by reference to plate VI.

This system was invented and patented by Mr. C. A. P. Turner of Minneapolis, about 1905 . Many of the later girderless systems are considered infringments of the patent, and have been vigorously prosecuted.

The floors have been used with spans from 16 to 30 feet, and for loads from 100 to 500 pounds per square foot. They are not economical for light loads, and hence are used chiefly in factory buildings and warehouses.

Plain round bars are used for reinforcement, as the engineer is strongly opposed to deformed bars of any kind. The method of placing the bars is easily understood from Plate VI. The flaring capital, with the heavy bars extending into the column and bent out radially into the slab, combined with the circumferential reinforcement, provides amply for shear over the column, which is the most dangerous section.

In the design of the slab, a bending moment of 1/50 WL is used. The constant 1/50 was obtained by measuring the stress in the steel for a certain load in an actual test, and solving from the equation

$$KWL = A_s .85\, d\, f_s$$

Knowing the load W, the span L, the area of the steel A, the depth d, and the stress in the steel f_s, the constant K was determined as 1/50. This is a very small value for the moment, as most building ordinances require that all floors shall be designed for a moment of 1/25 WL

at the center. The engineer computes that for a moment of 1/50 W L the deflection should be 1/7000 $\frac{W L^3}{A_s d^2}$, and he claims that in many tests the measured deflections have borne out the accuracy of this formula.

As in all girderless systems, the centering required is very simple.

Some of the buildings in which this system was used are as follows:

John Deere Plow Co. Building - Omaha

Bostwick - Braun Hardware House - Toledo, Ohio

T. &. B. Moose Building - Chicago

Grellet Collins Building - Philadelphia

"Soo" Line Freight Station - St. Paul

Many other buildings have been erected in St. Paul and Minneapolis using this system. In many of the buildings tests were made and deflections observed, but no records are available of any tests to destruction.

III. Floors with Concrete Beams and Girders

The oldest types of reinforced concrete building construction use flat slabs supported between concrete beams, these in turn being supported on girders and columns of concrete. By far the greater number of reinforced concrete floors have been constructed in this way. The forms are all built of wood, and the concrete for one entire floor is poured at one time, thus producing a monolithic construction.

There is no difficulty in designing a floor of this nature, each member being designed to carry the load imposed on it, according to the ordinary reinforced concrete beam theory; the same proceedure as with a wood floor construction. To place the reinforcement efficiently with a minimum of labor is the chief problem which has evolved; and many systems have been invented for its solution, especially in Europe, where more attention has been paid to reinforced concrete design. Many systems use only a different kind of reinforcing metal, while others use a distinct method of placing the reinforcement. The Hennebique System is perhaps the best known and oldest of all. The systems treated here are the Bertine, Chaudy, Columbian, Coignet, De Vallier, Gabriel, Hennebique, Kahn, Merrick, M System, and Wilson.

1. Bertine

Plate VII.

The Bertine system is typical of a great many systems of lesser importance, in which the floor slab is composed of a number of reinforced concrete tee-beams connected together. As a rule each

engineer designs his own system, and this particular type, or Bertine system, has never gained very great prominence.

Such floors can be used for spans of about 16 feet and develope considerable strength. The floor with dimensions as shown in plate VII. was designed for a load of 450 pounds.

The reinforcement consists of rods 1 inch in diameter, to take both tension and compression. The beam reinforcement for this system is rather distinctive, as shown, the stirrups being of 5/16" rods.

In this system, and in all similar systems, the tee-beams and supporting girders are designed according to the standard theory of reinforced concrete beam design, as given in all textbooks on the subject.

This system was used by Bertine and Son, Engineers, on the Bush Terminal Company Factory, at South Brooklyn, New York.

As each engineer will design his floors somewhat differently from every one else, and as the number of such designs is unlimited, no attempt will be made to consider all of such systems.

2. Chaudy System

Plate VIII.

This is a European system used chiefly in France, the main feature being double reinforced beams.

It was invented by Mr. Chaudy of Paris. The floors are designed as a series of T-beams connected to each other. The compressive and tensile reinforcement of the beam is connected by small rods which act as stirrups. The concrete in the beam is considered as

only a web connecting the reinforcing steel. See Plate VIII.

3. Coignet System

Plate IX.

This system is very similar to the previous one, the main difference being in the fabricating of the stirrup. This is shown in Plate IX, together with other systems using a similar form of reinforcement. In all these systems the compressive reinforcement is lighter than the tensile. The floor itself is designed as a series of connected T-beams. These systems are used to some extent in France.

4. De Valliere System

Plate X.

Another system differing only in the method of reinforcement is the De Valliere system, also originating in France. In this system no compressive reinforcement is used. The peculiar web reinforcement which is shown in Plate X is the distinguishing feature.

5. Gabriel System

Plate XI.

This is at present a rather unimportant system, sometimes considered as an offshoot of the Kahn System. It was designed by the Gabriel Reinforcement Co., and possesses several more or less distinctive features. The method of web reinforcement is shown in plate XI., also the beam connection to the column; woven wire is used for slab reinforcement. By increasing the depth of beams and girders

long distances may be spanned and heavy loads carried.

6. Hennebique System

Plate XII.

This system is one of the first successful systems of reinforced concrete construction. It is a monolithic construction of columns, girders, beams and slabs, with distinctive reinforcement, as shown in Plate XII. An arched slab is also sometimes used between beams.

This system was invented in France by Hennebique about 1885, and has been used extensively throughout Europe and lately in the United States, where it was patented in 1898. The patent rights are controlled by the Hennebique Construction Company, with its main office at New York City, and branch offices in many of the larger cities. It is claimed that over one hundred million dollars worth of work has been erected under the supervision of this company.

This system is well adapted to long spans, girders of 50 foot span being quite common. It is also adapted to heavy loads, ranging up to 200 pounds live load per square foot.

Round rods are generally used for reinforcement in slabs and beams, as shown in Plate XII, the ends being split and flared out to give a good grip. In this system some of the tensile reinforcement was first bent up near the end of the beams to provide for shear and negative bending moment. Shear is further provided for by vertical stirrups composed of flat bars bent around the tensile reinforcement in a U-shape and hooked at the top.

Ordinary flexure formulas for reinforced concrete may be used in the design of this system.

A few of the more important buildings constructed with this system are as follows:

William McKinley High School - St. Louis

United States Express Co. Stables - Jersey City, N. J.

Metropolitan Life Insurance Company - Bronxville, N. Y.

Princeton University Dormitories - Princeton, N. J.

Many tests have been performed on actual buildings and deflections measured, showing that the floors are entirely safe, but no tests to destruction with measurement of actual stresses have been reported.

7. Kahn System

Plate XIII.

The Trussed Concrete Steel Company of Detroit uses a type of construction very similar to the Hennebique, except for the use of their patent Kahn bar for reinforcement. This bar is well shown in Fig. 3, Plate XIII. This system has had considerable success in America, and the bars have been used to some extent in Europe.

In all other particulars, this construction is similar to the Hennebique system, and it may be designed in the same manner, except for the shear taken up by the projecting pins.

Floredome and Floretyle

Plate XIII.

This company also employs a construction using tile, (see Chapter VII) and one using hollow metal forms forming coffers on the under side, as shown in Plate XIII. This system is entirely

different from the preceding systems, as it divides the floor into a series of adjacent T-beams running either one or two ways as shown in Plate XIII. This system is comparatively new, and has not gained much prominence as yet.

It is not especially well adapted to heavy loads or long spans.

Kahn bars are used for reinforcing the T-beams, both the bars and the metal domes being supported on Hy-rib, which acts as partial self-centering, and may be plastered on the under side to form a flat ceiling.

Tables for design are furnished by the company, computed with ordinary theory for a bending moment of 1/10 W L. Actual data from tests, however, is lacking.

Some of the more important buildings in which this type of construction has been used are: The Railway Exchange Building, St. Louis, Mo.; Packard Service Building, Los Angeles, Cal.; and the Mt. Tabor School, Portland, Ore.

8. Merrick System

Plate XIV.

This system is similar to the Kahn Floredome system previously described, using a hollow metal dome, similar to a tile system. By reference to the drawing, Plate XIV, it is seen that the floor is comprised of a number of beams laid adjoining, with a coverplate and an underneath plate of concrete.

The system has been used considerably in the East. Patent rights are held by Mr. E. Merrick of New York.

Spans 16 to 18 feet are used for loads of 75 # to 100 #. Dimensions for a 14 foot span are shown in the illustration.

The reinforcement consists of 3/16" rods laid as shown. The system is designed as a series of rectangular beams, the lower or ceiling slab of 2" being of cinder concrete, while the remainder is stone concrete.

Ordinary flat centering is required.

9. System M

Plate XV.

System M has been put on the market by The Standard Concrete Steel Company of New York City, and has been used to a considerable extent in the East. It is well adapted to long spans and heavy loads. Floor beams up to 50 feet in length have been used with success, and several buildings have been designed for floor loads of 250 # per square foot.

In this style of construction the tension reinforcement for the beams and girders is composed of rolled sections bolted or riveted to metal columns,(sometimes of cast iron) which form the column reinforcement. Stirrups are provided by passing rods through the web of the rolled sections and bending them up. Rods or metal fabric may be used for the slab reinforcement.

The common theories of design may be applied to this system. The steel skeleton is constructed ahead of the concrete and assists in supporting the centering.

Some of the important buildings constructed in this system are: The Maryland State Tobacco Warehouse; 102-4 Fifth Ave. Building,

New York City; Building at Grand and Mercer Sts., New York City, and the United States Medical Stores, Greenwich, New York.

Very little information is obtainable regarding tests. A portion of the floor of the Maryland State Tobacco Warehouse, designed for 200 # per square foot, successfully withstood a load of 870 # per square foot with but slight deflection.

10. Wilson System

Plate XVI.

In this system the columns, beams, and girders are of reinforced concrete, while the floor proper is of plank. It has been developed from the ordinary mill or slow burning construction, differing from it in using reinforced concrete for the supporting members. This system was patented by the Wilson System Company of New York City in 1911, and has been used in a number of eastern buildings. It is well adapted to long spans and heavy loads.

The reinforcement is not a distinguishing feature, common bars with rod stirrups being used. The common beam and column theory is all that is necessary for design.

This system has been used in a number of buildings in Massachusetts among which are: The Stoughton Rubber Co., Stoughton, Mass.; Shoe Factory for Chas. W. Dean and Company, Motick, Mass.; and Printing Plant for T. Mong & Son, Greenfield, Mass.

IV. Floors with Steel Beams and Concrete Slabs

The increasing height of buildings in large cities has led to the development of a floor construction using a steel frame work, with a reinforced concrete slab between beams. This is because the heavy loads necessitate the use of concrete columns of such large diameters as to make their use prohibitive, while the difficulty of attaching concrete beams to steel columns makes advisable the use of steel for the beams and girders as well.

The steel frame work in this type of construction can be erected rapidly, and the concrete slabs put in later. In all the best types, the concrete is also placed around the beams and columns, thus forming a light, rigid, and fireproof building construction. This type has come to be used also in smaller buildings, on account of its lightness and ease of construction, combined with fire-proofness.

In order to secure a flat ceiling with this type, either a suspended ceiling must be used, or the slab placed lower and a cinder fill put in. Other items of expense are the complicated wood forms around the beams, and the placing of reinforcement, which have led to the development of stiff reinforcing plates, of combination tile systems, and of a built up fabric reinforcement. All of these departures will be treated in later chapters.

Unlike the previous type, in which most of the systems originated in Europe, the systems of this type are for the most part American. Those treated here are the Columbian, Kahn, Matrai, Metropolitan, Roebling and White.

1. Columbian System

Plate XVII.

The distinguishing feature of the Columbian system is the Columbian reinforcing bars and the methods of connecting them to the metal beams which are usually used as the supporting members; however, concrete beams reinforced with Columbian bars are sometimes used. Plate XVII shows the general appearance and a number of the details of this system. In the past this system has been used to some extent in the United States, but at present it is used very little.

It may be used with long spans and heavy loads and is easily designed. The reinforcing steel is a peculiar rolled section, drawings of which are shown in Plate XVII.

2. Matrai System

Plate XVIII.

This is a French system invented by M. Matrai, and used to some extent in France. It is really an inverted arch, as shown in Plate XVIII, in which the stress is taken up by tension wire cables forming a complicated network. The beams supporting the panel edges are sometimes constructed of reinforced concrete, using a reinforcement as shown in Fig. 3, Plate XVIII. Panels 25 x 12 feet have been used with success.

In designing this system it is assumed that the wire cables carry all of the stress, the concrete acting as a filler. These wires are attached as near the ends of the beam as possible, in order to reduce the moment. This system was used in the construction of

the Maison d' Education de la Legion d' Honneur.

3. Metropolitan System

Plate XIX.

This system was formerly known as the Manhattan, and is manfactured by the Metropolitan Fireproofing Company of Trenton, N. J. The reinforcement consists of twisted galvanized wires supported by beams as shown in Plate XIX. A 7/8 in. round rod is placed in the center of the span and parallel to the beams, to bring the wires to a uniform deflection. The use of this system is not extensive at the present time.

4. Roebling System

Plate XX.

The Roebling System is one of the standard systems for use with steel beams. Its distinctive feature is reinforcement of flat bars set on edge and spaced with separators. It has had wide commercial success in all parts of the country; in New York, Chicago, in the West and in Canada.

The system was invented by John A. Roebling, the designer of the Brooklyn Bridge, and patent rights are held by the Roebling Construction Company with their main office at New York City.

The maximum span used is 16 feet, although it is more economical to use smaller spans. The loads supported are fairly large, 150 pounds being usual. Cinder concrete is often used, a 1-2-5 mixture being common.

The reinforcement consists of either 2" x 1/8" bars 16" on centers or 3" x 1/4" bars 12" on centers. The bars are set on edge and held upright by separators spaced about 2 1/2 feet, and made of No. 5 rounds bent over the flat edge of the bar. The ends of the bars are fastened to the steel beams in various ways, as shown in Plate XX, or may be simply laid over the beams.

Slabs may be designed in the ordinary way, but it is customary to require a deflection test before accepting work.

The centering required, as in all similar systems, is quite complicated, on account of the beam fireproofing. The beams are usually wrapped with wire, or clips are used to tie the concrete to the beams.

In the past this system has been used in a great many buildings, although its popularity is on the wane.

Tests have been mostly of deflections.

Costs given by Mc Arthur for 1910 are as follows:

	per sq.ft.	span	depth of beams
Flat, with Ceiling	20¢	7'	10"
" without "	17¢	7'	10"
4" Slab	14¢	4'	4"

5. White System

Plate XXI.

By reference to Plate XXI, it is seen that the White System is very similar to the Roebling system, except that round bars are used for reinforcement instead of flat bars. This system is used extensively throughout the East, especially in New York.

It was patented about 1903, the rights being held by the White Fireproofing Company of New York City.

The loads range from 100 to 200 pounds for spans of between 6 and 8 feet. For beams 8'- 0" on centers a 4" slab is used, of 1-2-5 cinder concrete, weighing 59 #/sq.ft.

The reinforcement consists of 9/16" round rods 9" on centers, fastened to the steel beams in different ways, as shown in the illustration.

These slabs can be designed in the usual manner, but in cities the loads allowed are generally based on tests rather than on design.

A few of the buildings using this system are:

Germania Life Building - New York

Union Theological Seminary - New York

Globe Theater - New York

Hotel Kimball - Springfield, Mass.

Confederation Life Building - Toronto

The system was tested officially by the New York Building Department, and the slab carried a load of 600 pounds per square foot easily after the completion of a fire and water test of four hours.

V. Arch Construction

The arch construction represents the most economical type of floor as far as economical disposition of material is concerned, but the great cost of curved wooden forms is a serious drawback to its use. In fact, except with small spans where a mesh or plate can be sprung between supports, the cost of centering almost prohibits the use of arched concrete floors.

While there is no accurate theory to determine the strength of such floors, the strength actually developed by these arches, as shown by numerous tests, is very remarkable. Arches only two or three inches thick at the crown will sustain loads of 500 to 1000 pounds per square foot. Provision must always be made to take up the thrust of these arches, and while little steel reinforcing is needed in the arch itself, the amount used in tie rods to take up the thrust is almost equal to the amount needed in a flat slab of the same span.

Almost all systems which employ flexible reinforcement can be used in arch construction, and will develope greater strength in this manner; but the economy is usually slight. The difficulty in securing a presentable ceiling, which cannot be done without suspending a separate flat ceiling, is also a drawback to its use.

1. Golding Ribbed Arch

Plate XXII.

This arch is plainly shown in the illustration, Plate XXII. It was invented by Golding, the inventor of the first expanded metal.

The reinforcement consists of expanded metal, while the arched ribs are used for stiffening. This provides an effective use of material, but the ultimate economy of the system is doubtful.

2. Roebling Arch

A Roebling floor arch is shown in Fig. 6, Plate XX. This was one of the first arch systems to be used, and is typical of all the systems using fabric reinforcement, but in recent years it has practically gone out of use. It is controlled by the same company as that controlling the Roebling flat arch.

It is claimed that very heavy loads can be supported by these arches, based on results of actual tests, as all theories of design are inaccurate. Cinder concrete is generally used.

The reinforcement consists of wire lath with 3/16" rods interlaced, 9" on centers. This stiffens the lath so that it can be sprung between beams, and the concrete poured in without the use of centering.

3. Rolled Section Arch

Plate XXIII.

In Europe rolled sections are used to reinforce floor arches. Three of the more common arch systems, the Monier, the Melan, and the Wuench, are shown in Plate XXIII. It is easily seen that enormous strength can be developed in this way with light slabs, but the expense of curving the rolled sections is too great to allow of its use except in special cases. In bridge floors their use is common.

The sections used are angles or tees, and these are curved to give a rise of about 1/20 of the span.

VI. Sectional Systems

Sectional systems of reinforced concrete floors differ from all other systems in that members of reinforced concrete are cast in moulds, and after drying are carried to the building site and set in place, the same as wooden joists.

In this way all centering is eliminated. The members can be reinforced and poured under close supervision, and a uniform product is assured. They can be built under cover and allowed to harden any required length of time, so that building work can proceed in all kinds of weather. On the other hand, a structure of this nature has not quite the same rigidity as a monolithic structure.

In all concrete work, the labor item is by far the most important item of cost, and centering causes the largest part of the labor cost. As these systems require no centering, and as factory labor is far cheaper than field labor, these systems should present a considerable reduction in cost; in fact, this is the greatest argument in their favor. In Europe, where these systems originated, this has indeed proved true, but in this country the scattered cities and the high railroad rates have so increased the transportation costs as to offset any gain. Then, too, the use of ready built members is scarcely feasible where many floor openings are required; it is only in straight work that it can be used with any degree of success.

For these reasons these systems have not met the same success in America that they have in Europe. Several systems have been withdrawn from the market, including the "Hollow Concrete I Arch System", and none have gained very extensive commercial use. Those

considered here will be the Siegwart Beam, the Unit System, the Vaughan, and the Visintini System.

1. Siegwart Beam System

Plate XXIV.

As yet this system has not been used to any great extent in this country, although its use is rapidly increasing. In Europe the manufacture of Siegwart Beams is carried on in about 40 different cities, and over 40,000 sq. yds. are turned out per year. Only one factory is located in the United States.

The system is patented. It consists of flat hollow reinforced beams, which may be supported at their ends by rolled steel sections, as shown in Plate XXIV. The top is a little narrower than the bottom, and the sides have small grooves; the space thus formed is filled with grout, cementing the beams together.

This floor may be designed for heavy loads, and may be used for reasonably long spans. The reinforcement is simple, consisting of rods and stirrups, and the theory is that of simple reinforced concrete beams.

The cost of this system is reasonably low, except when the freight charges are excessive.

2. Unit Bilt System

Plate XXV.

The Unit Bilt System differs from the Siegwart Beam System in many ways. In the Unit Bilt System columns, girders, beams, wall

slabs, floor slabs, and roof slabs are all cast in the factory and sent to the job as units; moreover, these units are all solid. At the joint the reinforcing is allowed to project beyond the units, and the joint is poured with grout, thus cementing the members together. This method of construction is patented in the United States and in foreign countries. The general offices of the company are located at St. Louis, Mo.

The reinforcement is not a distinguishing feature, and common rods may be used.

As with other unit systems, one of the strongest points in its favor is the fact that no centering is needed.

3. Vaughan System

Plate XXVI.

This system is similar to the Siegwart Beam System, the main difference being in the section of the beam and in the form of stirrup. The section of these beams is roughly an I beam, as shown in Plate XXVI. The makers of this product are the Vaughan Company of Chicago. Patents have been applied for.

The reinforcement is simple, consisting of rods in the lower portion and a peculiar form of stirrup, as shown in Fig. 3, Plate XXVI.

The company gives a table of dimensions for spans up to 25' and loads up to 250 # per square foot, using the stress in the steel as 16,000 # per square inch, the stress in the concrete as 750 # per square inch, and $M = 1/8\ wl^2$.

A beam was tested by the company, in which it is claimed

that the stress in the steel reached 50357 # per sq. in.

4. Visintini System

Plate XXVII.

This is one of the oldest of the sectional systems, and one which has had the widest use, especially in Europe. As seen in Plate XXVII, it consists of beams of concrete, cored out and cast so as to form latticed girders. These beams are set side by side, to form a flat floor and ceiling.

Franz Visintini of Zurich, Switzerland invented the system, which was introduced in America for the first time by the Concrete Steel Engineering Company of New York in 1905.

The floors are very light, as can be easily seen, since the beams are only 6 to 12 inches wide and 6 to 8 inches deep. It is therefore best adapted to light loads, but long spans can be used up to 30 or 40 feet.

The top reinforcement is 1/4" round and the bottom 3/8" round, while the diagonal reinforcement is 1" x 1/8" straps, with holes punched, through which the top and bottom reinforcement is threaded.

These beams form a truss construction, the beams, Fig. 1, being Warren trusses, and the girders, Fig. 4, being Pratt trusses. Thus the stresses in the members can be fairly accurately determined by the method of truss analysis, a diagrom for which is shown in Fig. 5. Thus the members can be designed to carry the exact stress in tension or compression. Fig. 2 shows the method of anchoring the beams to the wall, and Fig. 3 shows the method of lifting them

with a rope and an iron frame which fits over the end.

This system was used in a factory for the Textile Machine Works of Reading, Pennsylvania.

VII. Combination Tile Systems

Another new form of construction which aims at economy is the combination tile and reinforced concrete system. Many attempts have been made to save the concrete in the lower part of the slab which is not used for tension or compression, by forming T-beams, placing the greater part of the concrete near the top of the slab, where it can be used for compression. The great cost of forms for this beam construction, however, generally more than offsets the saving in concrete. The combination tile systems, however, place a tile in the lower part of the slab, thus displacing part of the concrete without necessitating complicated forms.

Some of the best systems have eliminated the complicated centering still further by allowing the edge of the tile to rest directly on a plank, while the concrete is poured in the spaces, thus requiring only half of the area to be centered. In this way an economical floor is provided, consisting of a series of T-beams, while plaster may be applied directly to the underside of the tile and concrete, forming a flat ceiling.

This system has the added advantage of being very light, and where tile can be obtained cheaply, is certainly very economical, while allowing fairly long spans and heavy loads.

Forms of tile differ somewhat, and one-way and two-way reinforcement is used. In Europe there are a great many special shaped tile in common use, such as circular and part circular. Some of these are devised to carry pipes and wiring, thus concealing and fireproofing them.

These systems are similar to the steel Floredome and Floretyle system described in Chapter III, except that tile is used instead of the metal boxes.

The systems treated here are the Corr Tile, Fawcett, Kahn, Johnson, and Nolan Tile Systems.

1. Corr Tile Floor System

Plates XXVIII & XXIX.

The Corrugated Bar Company is the promoter of several systems of reinforced concrete floors, among which are three forms of two way tile construction. These three forms or systems differ only in the shape of tile used and in the way of setting them so as to close the holes at their ends.

In their handbook, the Company gives tables of thickness and loads for spans up to 30 x 38 feet. Corrugated bars are used for reinforcement. In designing this system, the company uses as a basis for their formulae and computations, $M = 1/32\ w\ l^2$, on square panels. This value is used for both positive and negative moments in fixed panels.

In this type of construction, the amount of centering is somewhat reduced, the tile answering the purpose in part.

In 1911 a panel of one of these floors designed for 150 # was tested up to 650# per square foot without reaching the yield point of the steel or producing excessive deflections.

2. Fawcett System

Plate XXX.

Strictly speaking, this is not a system of reinforced concrete for the steel beams really carry most of the load, while the concrete acts more as a filler above the tile. As shown in Plate XXX it consists of rolled beams supporting terra cotta lintels, which in turn support the concrete floor. It seems to be little used at the present time.

3. Kahn System One Way Tile

Plate XXXI.

This form of construction is like Corr Tile Floors in many respects, but it differs in one important feature in that the reinforcing is placed in only one direction. This permits the tile to be placed end to end and avoids the necessity of having a tile plate to stop up the holes. This system is a product of the Trussed Concrete Steel Company of Detroit. The company also has offices in London and Toronto.

The reinforcement is the Kahn Trussed Bar (see Fig. 3,Plate XIII). Plate XXXI shows the appearance of these bars in the floor. In their booklet "Kahn System Standards" the company gives several tables of safe loads for spans varying from 8 to 29 feet and thicknesses varying from 8 to 15 inches including tile and concrete. These tables are based on a bending moment of $1/10\ w\ l^2$, and from trial the allowable stresses are found to be 500 and 16000 in the concrete and steel respectively.

4. Johnson System

Plate XXXII.

This is a one way tile system patented by the National Fireproofing Company of Chicago. The general method of construction is shown in Plate XXXII.

It is seen that this system is similar to the others, but does not possess the advantage of dispensing with centering. Also in type 1 there is no concrete in compression, which would seem inefficient. Hence a design as a concrete beam will not be satisfactory.

5. Nolan Two Way Tile

Plate XXXIII.

The promoter of this system is J. S. Nolan and Company of Chicago. Both United States and foreign patents have either been granted or are pending. It has been used in various structures through the Central West, several of which are in Chicago. This system is very similar to Corr Tile Floors, differing from them only in minor details. Long spans and reasonably heavy loads may be used. However, it is best adapted to light loads and comparatively long spans. The design is that of a flat slab supported on four sides, thus making the computation of stresses somewhat difficult and uncertain. Havemeyer bars are used for reinforcement. No stirrups are used but the bars are bent up at the end.

The new West Side Y. M. C. A. of Chicago was constructed with floors of this system.

VIII. Plates Used Without Centering

Plates XXXIV to XXXVII.

Besides the sectional systems and the tile systems, a third system aiming at the reduction of the cost of centering makes use of self-centering plates. These are simply metal plates which are stiff enough to carry a concrete slab with but slight bracing. The plates are laid across steel or concrete beams in a number of different ways as shown in Plates XXXIV and XXXV, and concrete is placed on top, while the under side is plastered with cement plaster. The plate being thus fireproofed, serves as reinforcement for the slab.

The plates may be supported in various ways, and may be arched if desired as shown in the illustrations. There are a number of companies which manufacture these plates, many of them being very similar, as shown in Plates XXXVI and XXXVII. The more important types are shown and are as follows:

Fig. 1, Rib Truss -- Berger Mfg. Company

" 2, Multiplex Steel Plate --Berger Mfg. Company

" 3, Ferrolithic Plate -- Berger Mfg. Company

" 4, Self-centering -- General Fireproofing Company

" 5, Hyrib -- Trussed Concrete Steel Company

" 6, Corr Mesh -- Corrugated Bar Company

" 7, Ferroinclave -- Brown Hoisting Machinery Company

" 8, shows the various methods in which these plates may be obtained bent to shape.

These various forms of metal plates have been patented, but have not had a very wide commercial use as yet.

The spans are necessarily short varying from 3 to 10 feet between beams. Loads up to 200 # can be carried, with which the slab weighs about 60 # per square foot. The thickness of the slabs vary from 1 1/2 to 3 1/2 inches. For the longer spans the plates must be supported in two or three places.

The reinforcing plates generally come about 28 inches wide and 4 to 12 feet long. In those fabrics having raised ribs, the ribs are about 13/16 inches high and about 3 1/2 inches on centers. The area of the steel may be found from tables and may be verified by measurement. The following is given for Self-centering:

Gage	Sectional Area - sq.in.
28	.177
26	.213
24	.284

From this area and the dimensions of the slab, the safe load can easily be computed. In tables furnished by the same company, a stress in the steel of 16,000 and in the concrete of 800 pounds was assumed. It is somewhat questionable, however, if the entire sectional area can be considered effective in withstanding the moment, for the coat of cement plaster can scarcely be considered efficient fireproofing.

The elimination of centering is, of course, the principal advantage of this system. It is very well adapted to roof construction.

The Oil House of the Rumley Company, La Porte, Indiana, and the Ohio State Reformatory at Mansfield, Ohio, are examples of buildings with this type of floor.

IX. Systems with Fabric Reinforcement

Plates XXXVIII to XLI.

In order to reduce cost by simplifying the process of laying reinforcement, a great many forms of fabricated metal have been devised. As a rule this fabric is used with a construction employing steel beams, although it can also be used with concrete beams. The fabric may be supported in many different ways as shown in Plates XXXVIII and XXXIX.

Some of the heavier types are shown in Plate XL, the Hyatt, Donath, and Muller being flat bars on edge connected with cross bars to space them evenly, and the Chaudy being a row of round bars with a thin plate interwoven. These types are used principally in Europe and have not very wide-spread use.

Plate XLI illustrates some of the lighter types. Figure 1 illustrates Steelcrete Expanded Metal Lath, perhaps the best known and most widely used of all. It is made out of sheets of steel, split cold and pulled out to 3 to 8 times its original size. The sheets come in sizes of 12 to 72 inches in width and 8 feet in length. The thickness of plate varies from # 27 to # 3 gauge, and the size of the mesh from 3/8" to a 5" x 12". This metal was invented by Mr. Golding in 1890, and its manufacture in America is now in the hands of the Consolidated Expanded Metal Lath Companies, which is a consolidation of separate companies under different names in Chicago, Pittsburg, Boston, New York, Philadelphia, St. Louis, Washington, Buffalo, San Francisco, and Toronto.

The sectional area of this expanded metal may be obtained from tables.

Figure 2 illustrates Clinton Welded Wire, invented in 1840 and manufactured by the Clinton Wire Cloth Co. of Clinton, Massachusetts. The rectangular mesh varies from 3 by 8 to 8 by 10 inches, and is electrically welded at intersections. The carrying wires are #10 to #4, and the distributing wires #11 to #6. The mesh comes in 60 inch rolls.

Figure 3 shows Cottancin wire, a fabric used chiefly in Europe.

Figure 4 is Lockwoven Steel Fabric, manufactured by W. N. Wight and Company of New York. This has been extensively used for reinforcement during the last ten years. The longitudinal wires vary from #14 to #7, and the cross wires are #14, the mesh being 3 x 12 or 1 1/2 by 12 inches. The sheets are 54 inches wide.

Tie Locked Fabric, Figure 5, is a similar mesh using the peculiar shaped tie shown and manufactured by the International Fence and Fireproofing Company of Columbus, Ohio. This comes in sheets 45 to 60 inches wide and any length. The mesh is 4 by 6 inches, the wires #18 to #6 gauge. This company supports the fabric on wire cables for long spans.

A triangular mesh, Figure 6, has been used by the American System of Reinforcement, Chicago, since 1887. The wires are #7 and #11 gauge, the mesh 4 inches. This fabric has had wide use.

Rib Metal, Figure 7, manufactured by the Trussed Concrete Steel Company of Detroit, is a comparatively new product in which the cross members are formed from the same sheet of steel.

This type is best adapted to light loads, 75 # to 150 #, and short spans, 6 to 15 feet. Where the fabric is galvanized, cinder concrete may be used, giving a light dead load.

The sectional area is obtainable for all the various types of reinforcement shown, and the slab may be designed by the ordinary beam theory. Tests show that for short spans such slabs develope considerably greater strength than the design attributes to them, due to arch action in the slab, but this quantity is uncertain and it is best to rely on the usual theory for design.

Ordinary centering is required. The fireproofing of beams should not be carelessly done as is so often the case with this type.

The advantage of a fabricated mesh is economy in laying reinforcement and assurance of correct spacing. Moreover, the fabric can easily be bent to the top of the slab over beams to provide for negative bending moment.

Any number of buildings have been constructed with the use of some of these forms of reinforcement, and many tests have been performed. Below are the results of some tests on expanded metal slabs, it being the most widely used.

Tests on Expanded Metal Floors

No.	Where Made	Kind of concrete	Span ft.	Load per sq ft lbs.	Center Load lbs.	Deflection at center in.	Reinforced with expanded metal
1	N.Y.Sugar Refining Co.,Long Island City, L.I.	Cinder	4	--	40,000	0	3"-No.10
2	N.Y.Sugar Refining Co.,Long Island City, L.I.	"	4-10	--	37,000	3/8	3"-No.10
3	Larkin Soap Factory,Buffalo,N.Y.	"	4	2333		5/8	3"-No.10
4	Y.M.C.A Building, Buffalo, N. Y.	Cinder & Stone	17-8	800		0	3"-No.10 rods16"c-c
5	Edison Power House, New York, N. Y.	Cinder	5		122500	Arch	3"-No.10
6	Gov't Hospital for Insane, Washington, D. C.	"	6	1256		3/16	3"-No.10
7	Merchants Refrigerating Co., Jersey City, N. J.	"	7	2400		5/16	3"-No.10
8	Board of Harbor Commissioners,San Francisco, Cal	Stone	7	750		0	2 1/2"-No16
9	Columbia University, New York, N. Y.	"	15	600		5/8	6"-No.4 1/2" rods

X. Unit Frames

Plate XLII

Besides fabric reinforcement for slabs, several attempts have been made to secure a unit reinforcement for beams, to accomplish the same purpose, and from which unit frames have evolved. Plate XLII illustrates three of these.

Figure 1 is a frame manufactured by the American System of Reinforcement, Chicago. The tensile and shear reinforcement are rigidly attached to each other and the frames can be ordered to size ready to put into place.

Figure 2 is a frame manufactured by the Corrugated Bar Company of Buffalo, New York. The stirrups are pivoted to the longitudinal reinforcement of corrugated bars so as to produce a collapsible frame, facillitating shipment. The General Fireproofing Company of Youngstown manufacture a similar pin connected frame.

Figure 3 is a frame manufactured by the Pittsburg Steel Products Company, which was originally known as the Cummings Frame. The stirrups are placed at 45 degrees, made of 1/8" strips, 1 1/2 " wide, electrically welded to the longitudinal bars.

All of these frames decrease the labor cost of setting reinforcement, and insure its proper position in the beam. Where the factory is easy of access and the shipping costs not too large, their use should result in a considerable saving.

XI. Deformed Bars

Plates XLIII to XLV.

Many so-called systems have been patented, especially in America, which are distinctive in nothing except in having some form of deformed bar for reinforcement in order to secure a mechanical bond. The efficiency of such bars is questioned by many prominent engineers, and tests have shown that they increase the strength for initial slippage very little, although they raise the ultimate bond stress considerably.

Plate XLIII shows types of bars commonly used in Europe. The Hyatt bar has been treated in Chapter IX, and the Kahn bar is shown also in Plate XIII.

Other forms of bars used to some extent in America are shown in Plate XLIV.

Most of these bars sacrifice section area for mechanical bond and are therefore inefficient. The Havemeyer Bars, shown in Plate XLV, Figure 1, overcome this difficulty in a very ingenuous manner.

Other much used bars are the twisted square Ransome bars, for which the patent has expired, and the round and square corrugated bars. The Kahn Rib Bar is very similar.

Only those shown in Plate XLV are much used commercially at present in this country. In design, tables giving the sectional area of the bars are necessary. The design is then the same as for plain bars, except that some engineers allow a 50 per cent increase in the bond stress specified.

XII Design of Ten Typical Floor Panels
Plates XLV to L

1. Procedure.

In order to present the advantages of different floor systems in reinforced concrete, panels were designed using each of ten systems which seemed to be typical of a class, under four different conditions of spans and loads, making forty separate designs. Quantities of material were computed for each design and prices taken from Gilletts "Cost Data" were applied, thus giving estimates of cost. While these prices vary in different parts of the country, the relative value for different material is approximately the same, so that the figures are fairly accurate for comparative values.

The panel was considered to be one in the center of the building, and the beam and girder support for the panel was considered in estimating its weight and cost. In each case a bending moment was assumed consistent with good engineering practice, and the unit stresses assumed are constant and conservative.

In systems using steel beams fireproofing was considered, except for the bottom flanges of the arch system. The ceiling was neglected in all designs. The unit price per square foot of floor includes the cost of the entire panel complete.

Plates XLVI to LV give the tabulated results for the designs with the conditions governing each. Plate LVI gives the computed values of weight of steel and concrete per square foot, dead load, and cost per square foot, to facilitate the comparison.

In order to observe the variation of cost with the span

and with the load, for the different systems, values of cost for varying spans and loads are plotted on graphs, in Plates LVII and LVIII. Similar graphs showing the variation of dead load with spans and with live loads are given in Plates LIX and LX. The two sets of graphs do not show the same variation, because systems using a great deal of steel are light but have a heavy cost on account of the much greater cost of steel. The dead loads are important in affecting the ultimate cost of the building, as a large dead load means an increase in the size of columns and foundations.

2. Results.

The two types at the bottom of the list as regards price are the flat slab and the Kahn Floredome; the former is at the bottom for heavy loads and the latter for light loads. The latter has much the advantage as regards dead load, however.

In general, a small slope on Plate LVII indicates a system advantageous for heavy loads, while a small slope on Plate LVIII indicates a system advantageous for long spans. Both the Vaughan sectional system and a one way tile system are inexpensive for short spans, but run up rapidly with increase in span.

The other systems run on an average. The sudden rise of the expanded metal systems is due to the fact that the use of this system with such a long span is inadvisable; the slab would be less expensive with a central beam.

The Hennebique runs the nearest to an average, but it has the highest dead load of any. The Kahn Floredome and tile systems

have the lightest dead loads. The sudden increase in the dead load of the one way tile with increase in span is due to the fact that the system is inapplicable to long spans. The Turner flat slab has medium weight, but saves in cost in the small amount of steel. The other systems, the Roebling, Two Way Tile, Flat Plate, and Arched Plate are average in both cost and weight. No great saving is made by the saving in centering with the last two, the cost being greatly increased on account of the relatively large amount of steel needed.

3. Conclusions

From the comparison of the floor systems in reinforced concrete, we should predict a much more extensive use of flat slab construction of any standard type. Not only is the flat slab inexpensive, but it possesses many other advantages in simplicity, lighting area, and appearance.

Systems of combination tile and also those using hollow metal boxes are advantageous in many respects, and may be expected to come into more general use.

Sectional systems will undoubtedly be used to a greater extent, especially as the development of the country reduces transportation charges and as labor charges increase.

The use of arches is apparently on the wane and they are seldom used except with a self-centering plate; but even then their advantage is doubtful.

Such standard systems as the Hennebique are thoroughly dependable and applicable to all spans and loads. Their great dead

load, however, tends to destroy their efficiency in tall buildings.

Of the systems employing special forms of reinforcement, such as a particular wire or metal plate, there seems to be little choice. None of them are especially efficient, and their partial success has been due more to advertisement than anything else.

Steel plates for centering do not result in the great saving that is usually claimed for them, besides being far from perfect as regards fireproofing of metal; hence a great success for them is hardly to be expected. Unit frames and deformed bars have their place in floor construction, but their importance is likely to be overrated.

Finally, every system will have its use under some particular case, even if it be rather limited; while wide commercial success will depend more on the type of company promoting the system and upon advertisement, than upon any minor intrinsic advantage. The greatest field for research and invention is with flat slab and combination tile or metal floors.

• AKME • SYSTEM •

PLATE I

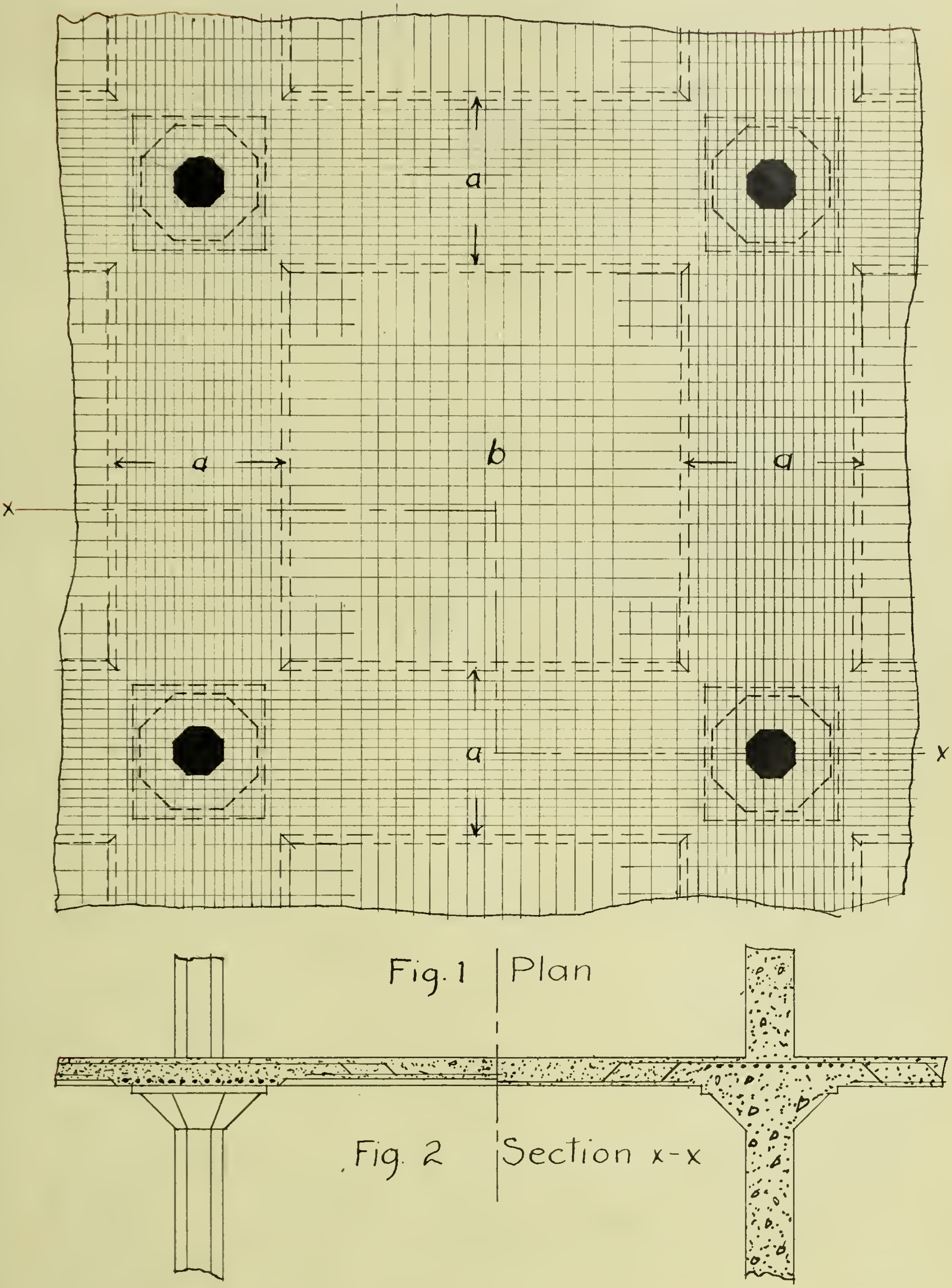


Fig. 1 | Plan

Fig. 2 | Section x - x

AKME SYSTEM

PLATE II

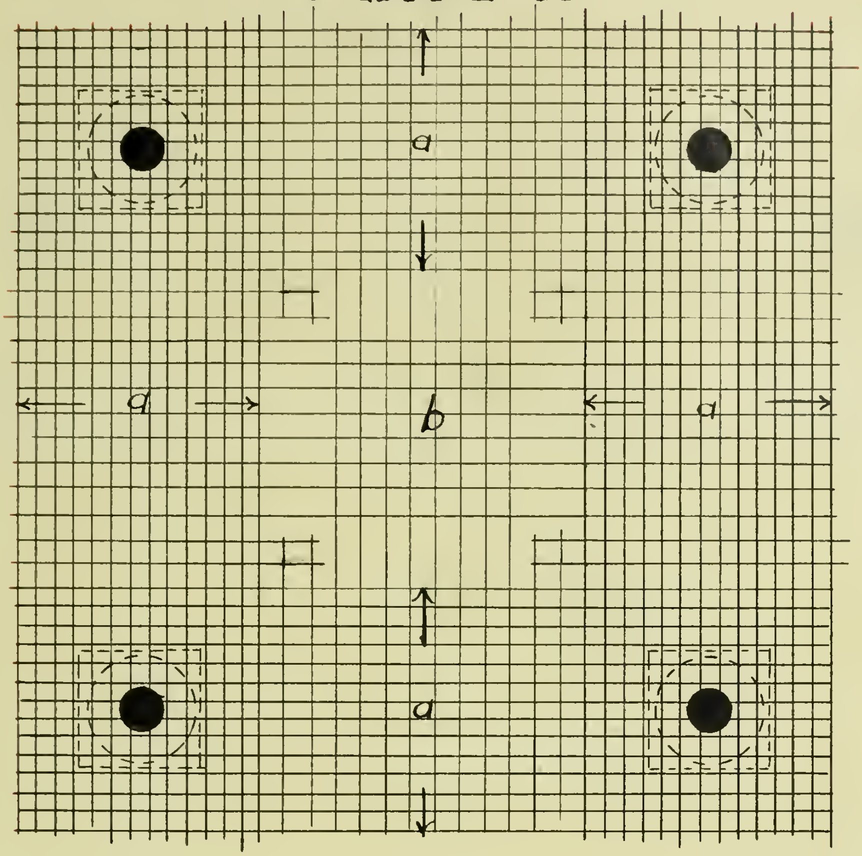


Fig. 1 Plan

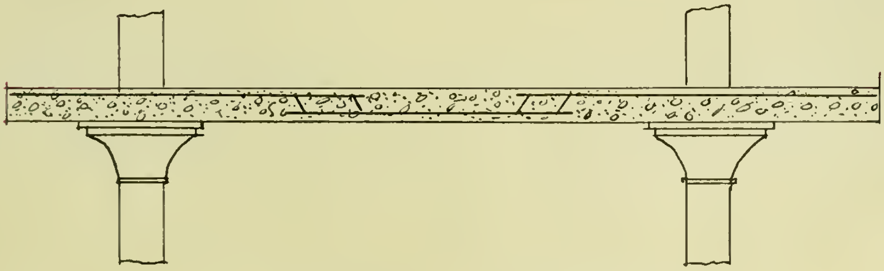


Fig. 2 Section

◦CANTILEVER◦FLAT◦SLAB◦SYSTEM◦

PLATE III

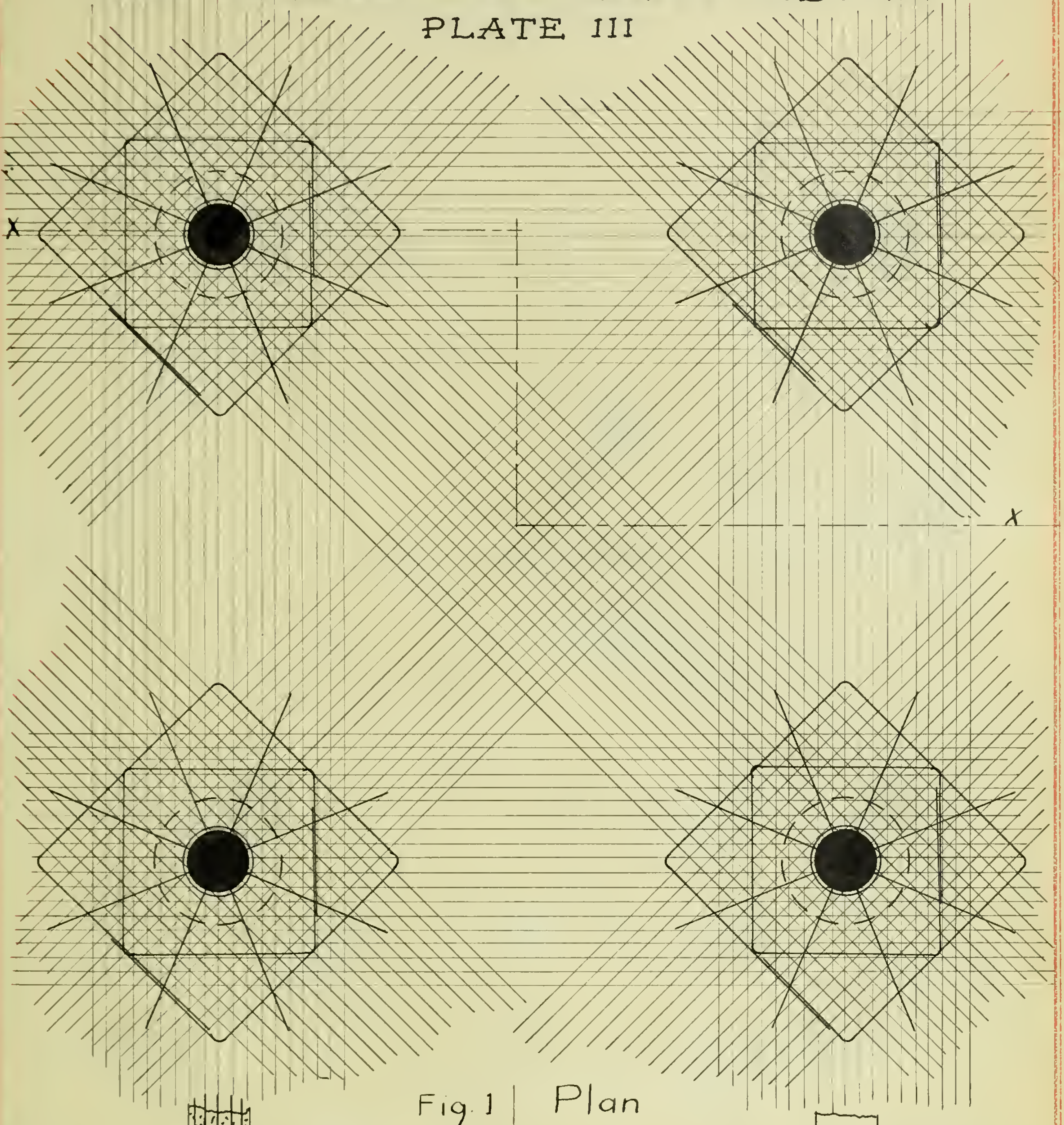


Fig. 1 Plan

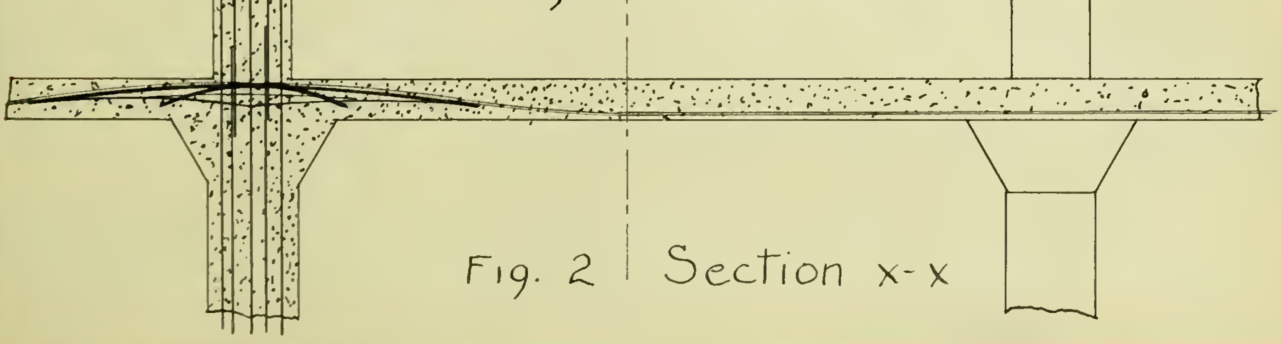


Fig. 2 Section x-x

∘ CORR-PLATE ∘ SYSTEM ∘

PLATE IV

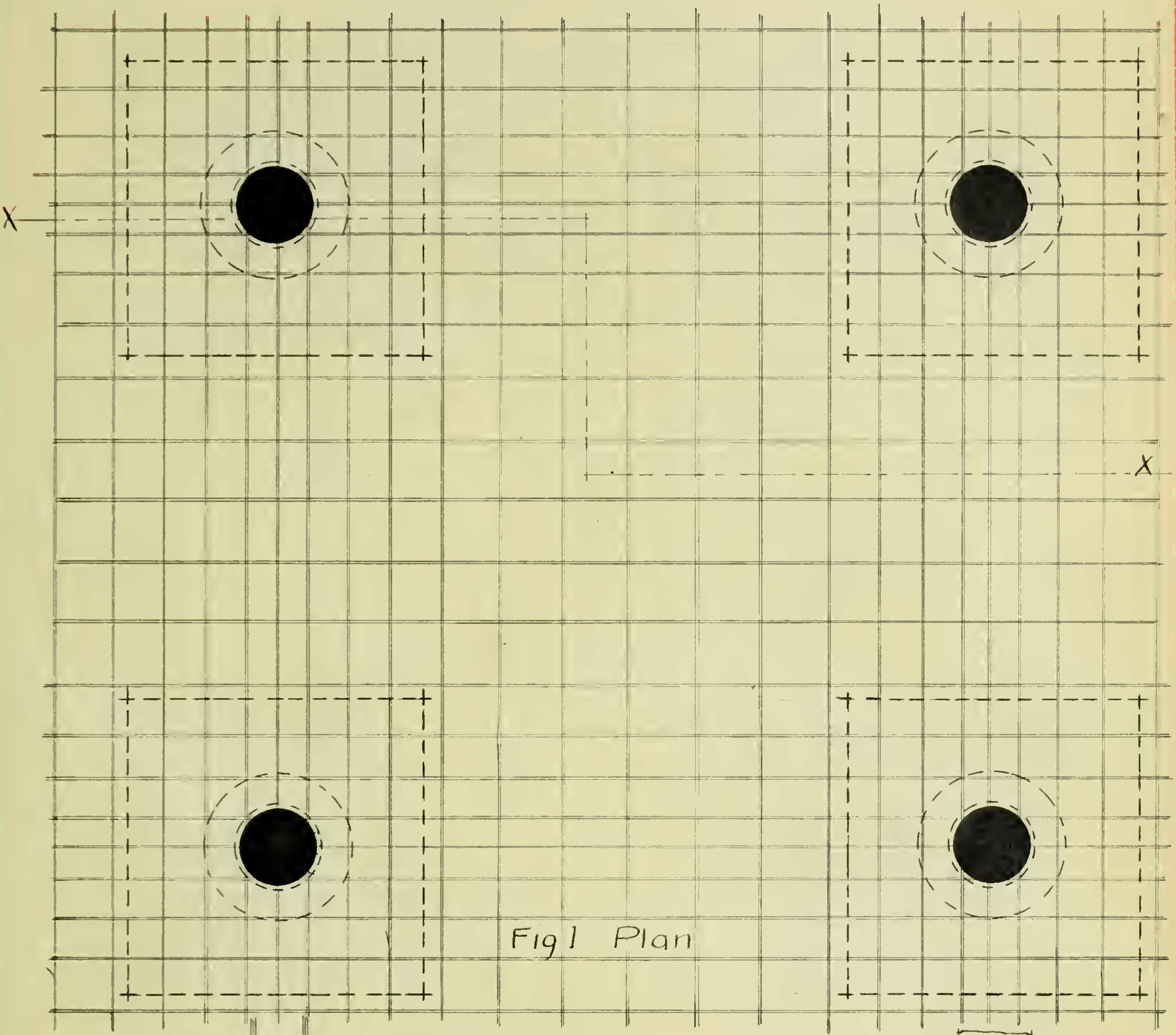


Fig 1 Plan

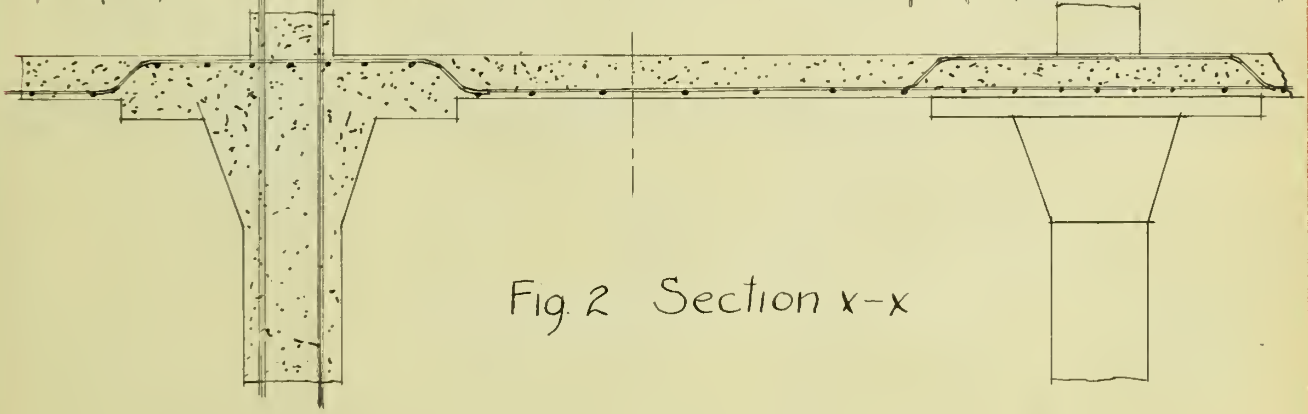


Fig. 2 Section x–x

• SPIDER • WEB • SYSTEM •

PLATE V

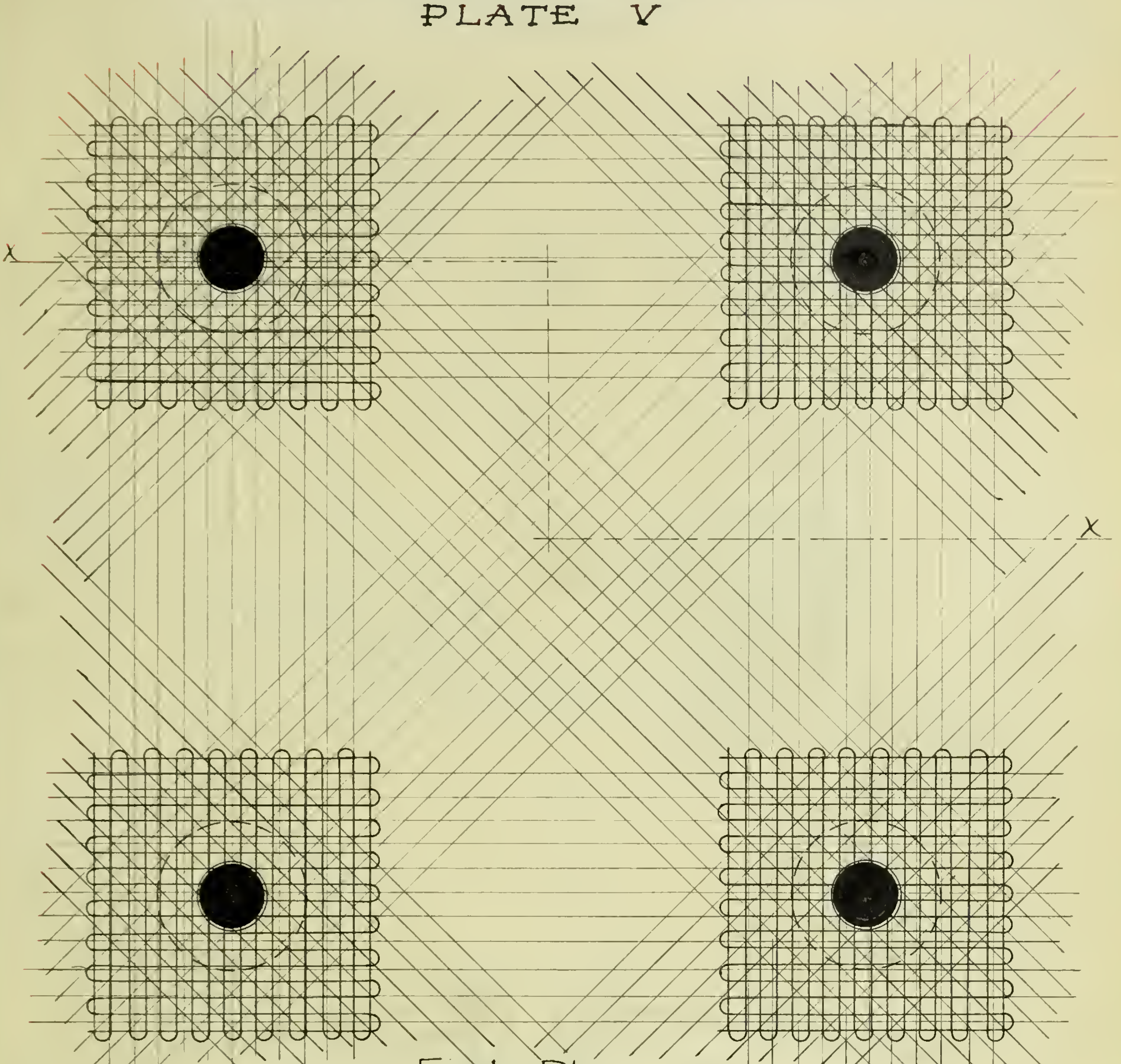


Fig 1 Plan

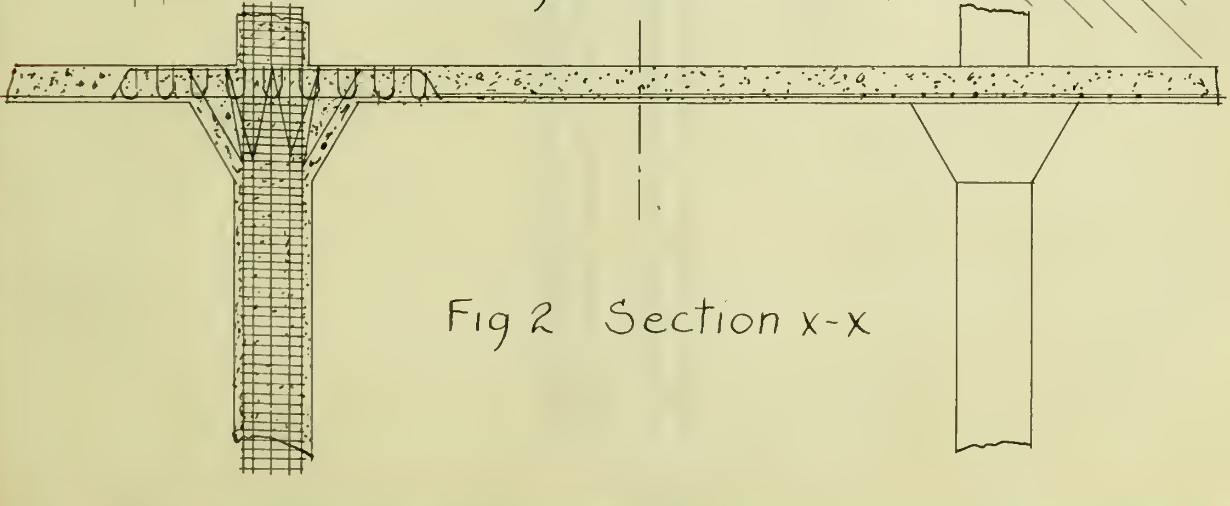


Fig 2 Section x-x

∘TURNER∘CANTILEVER∘SYSTEM∘

PLATE VI

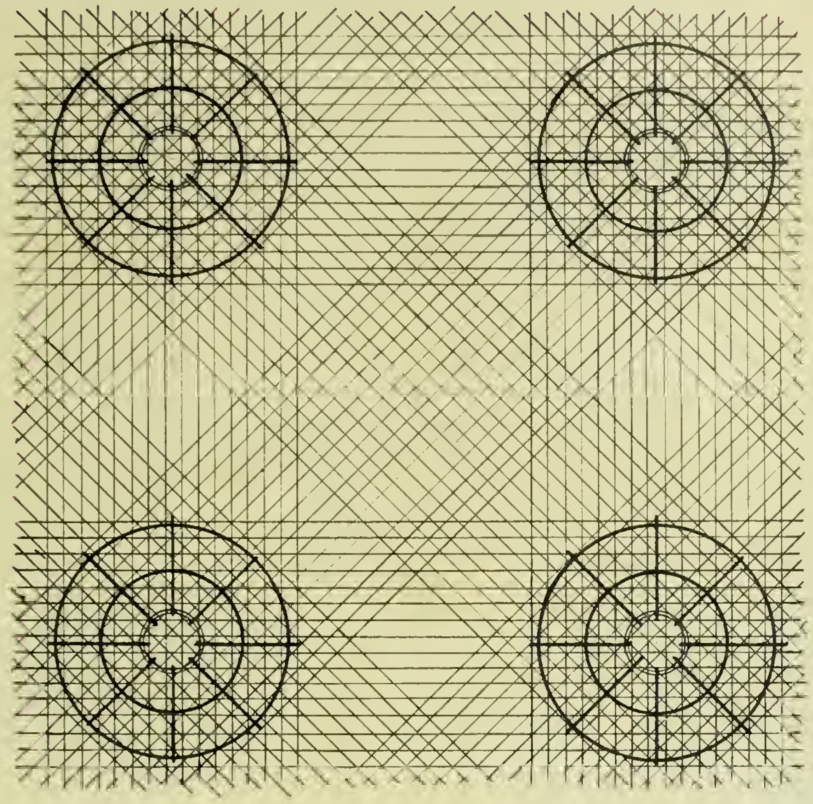


Fig 1 Plan

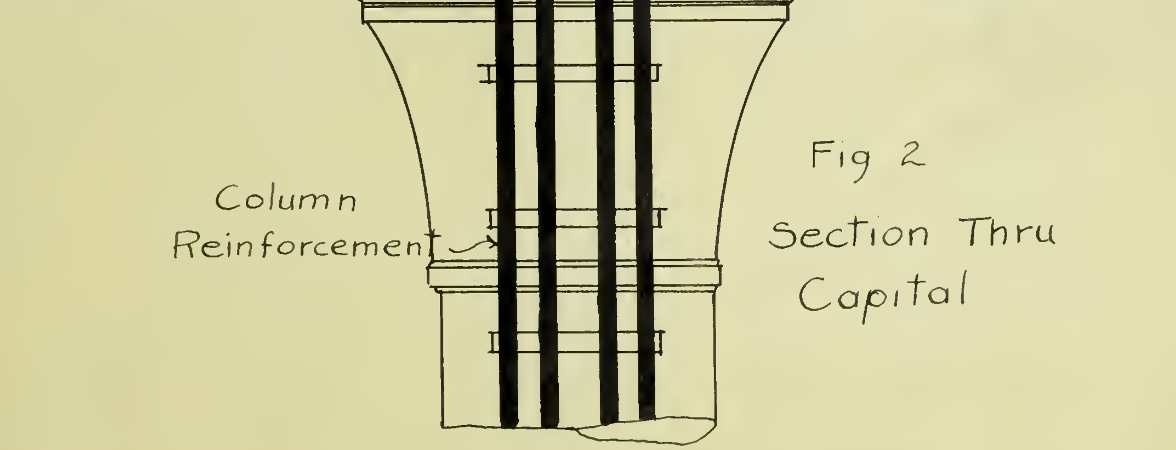
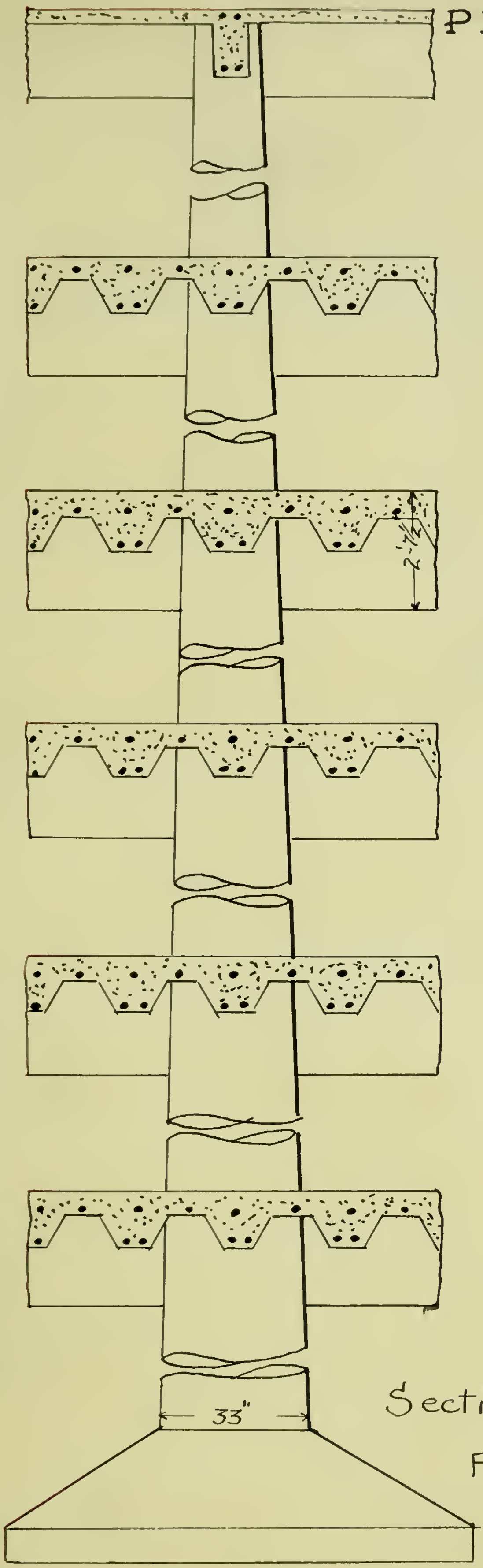


Fig 2
Section Thru
Capital

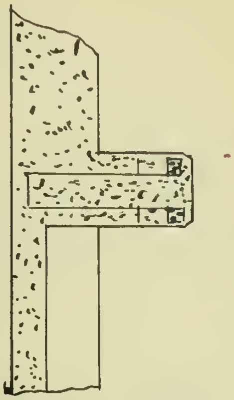
∘BERTINE∘SYSTEM∘

PLATE VII

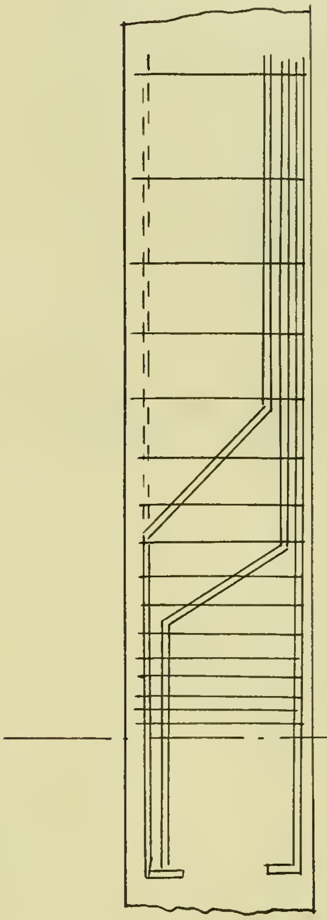


Section

Fig 1



Section



Beam Reinforcement

Fig. 2

∘ CHAUDY ∘ SYSTEM ∘

PLATE VIII

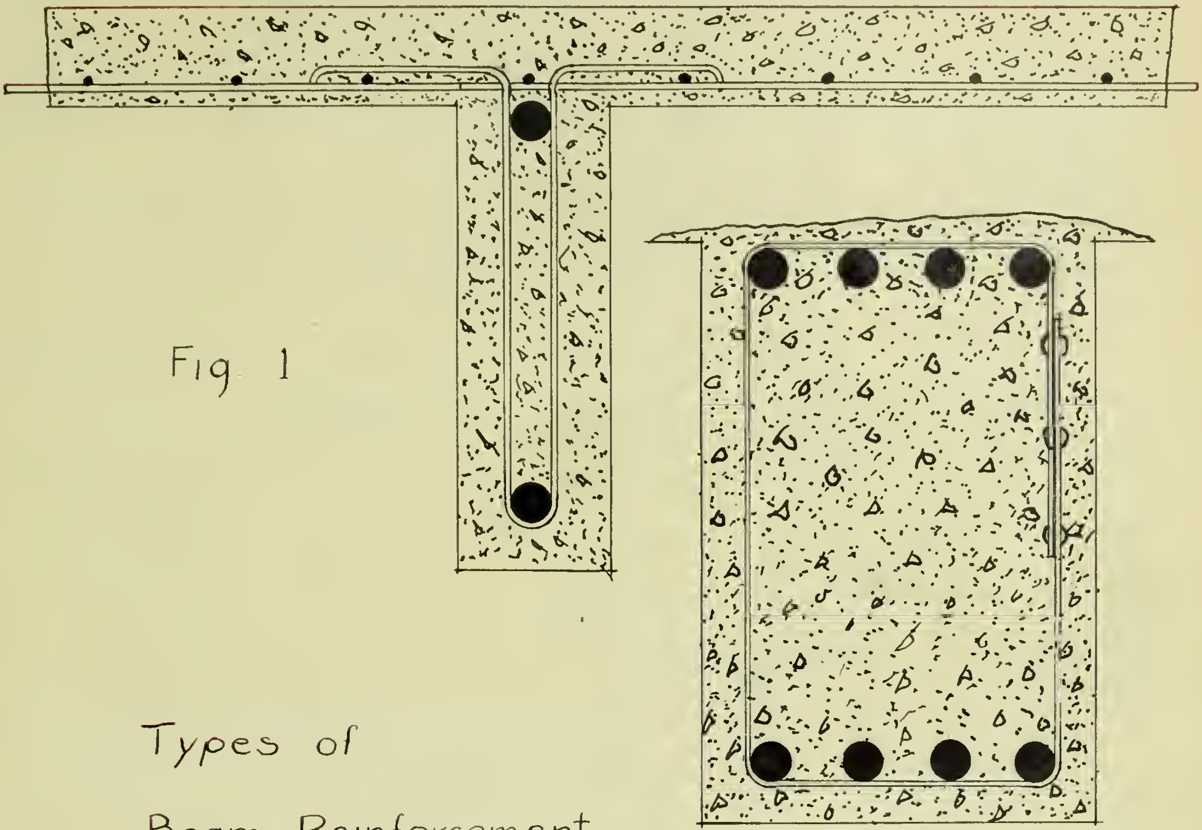


Fig. 1

Types of Beam Reinforcement

Fig. 2

•TYPES•OF•BEAM•REINFORCEMENT•

PLATE IX

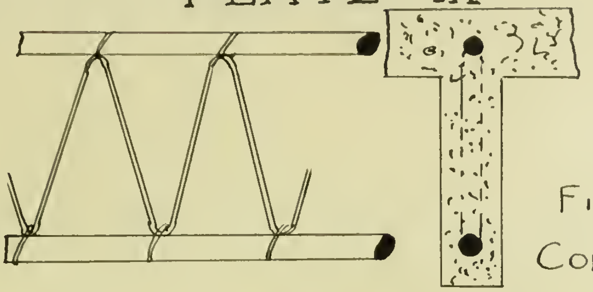


Fig 1
Coignet

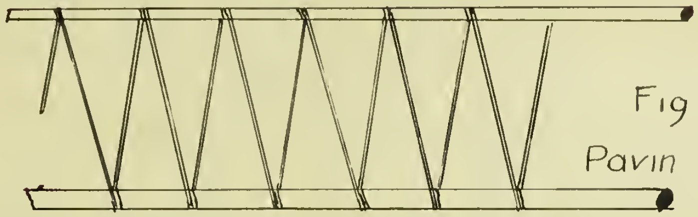


Fig 2
Pavin De Lavarge

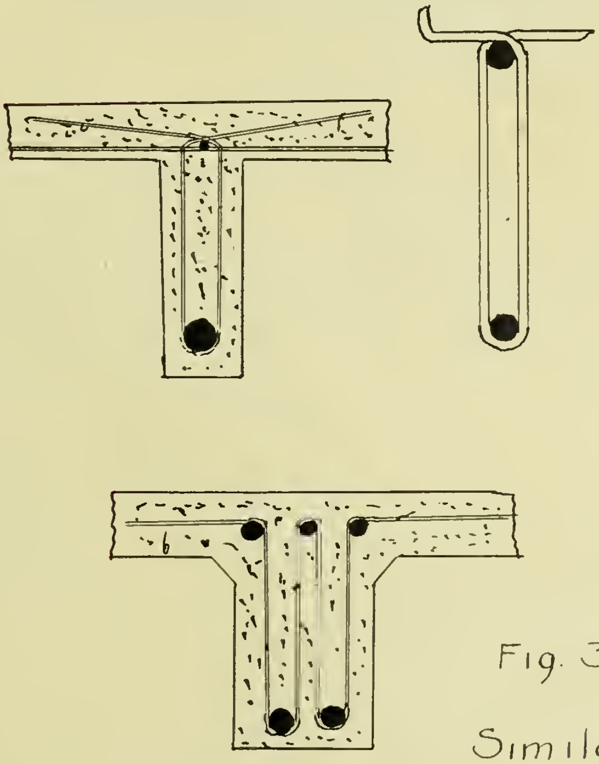


Fig. 3

Similar
Systems

∘DE∘VALLIERE ∘SYSTEM∘
PLATE X

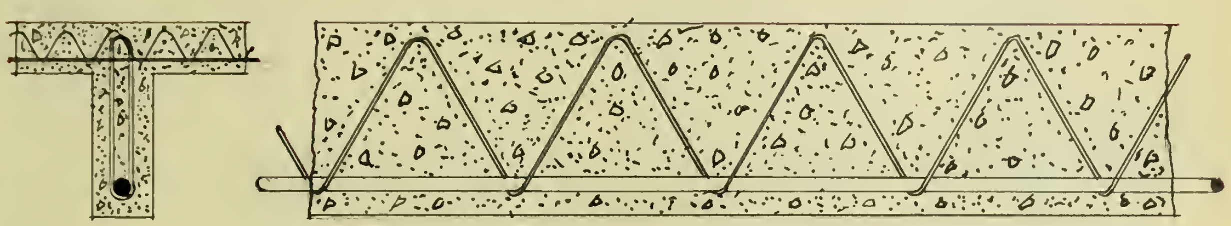


Fig 1

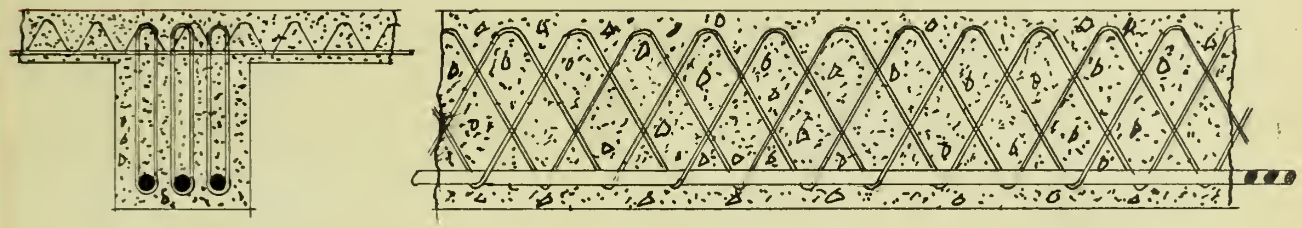


Fig 2

·GABRIEL·SYSTEM·

PLATE XI

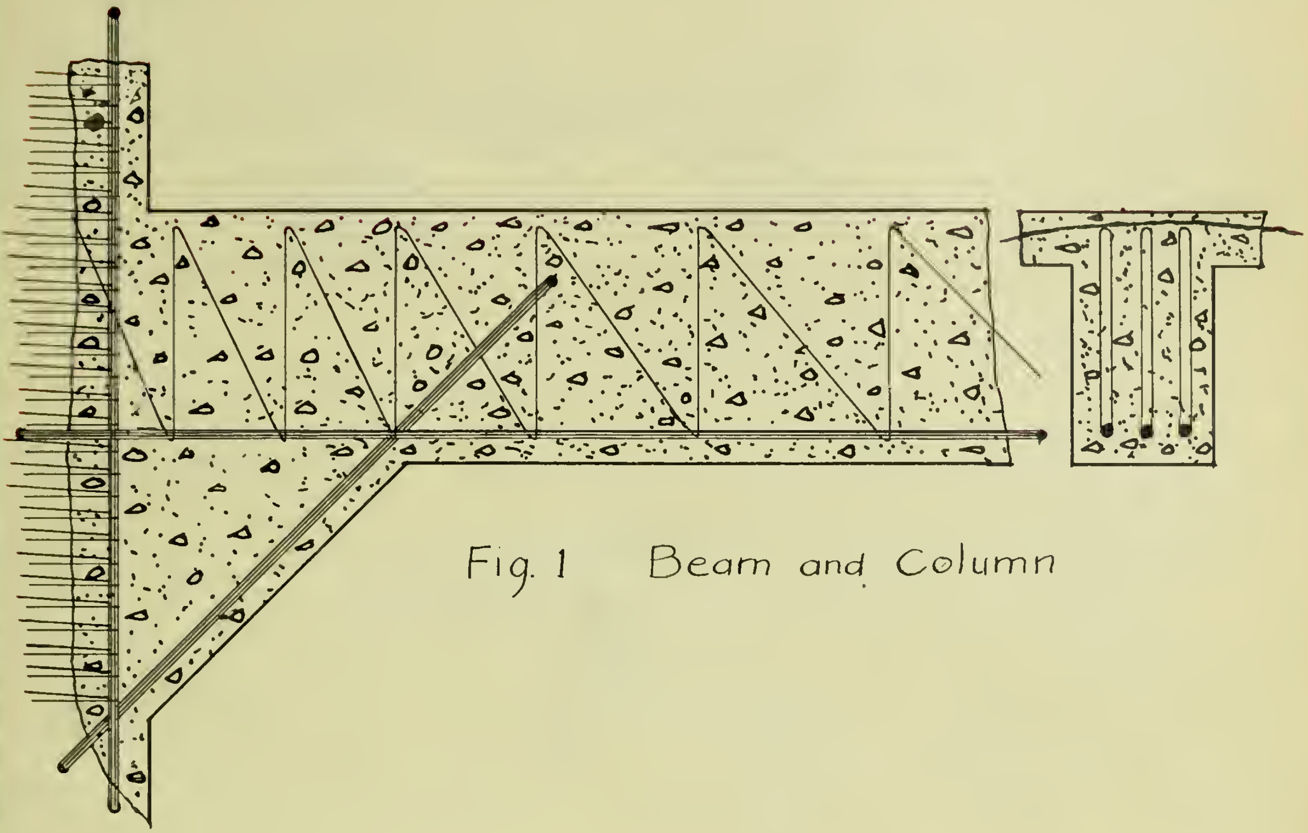


Fig. 1 Beam and Column

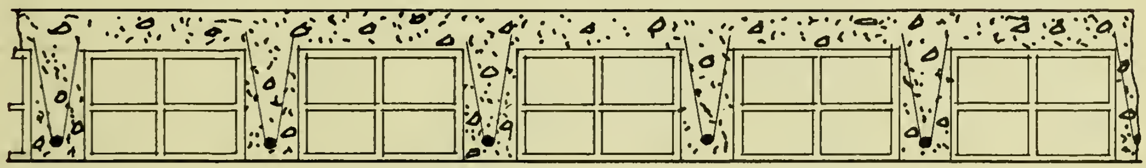


Fig. 2. Floor Slab

◦HENNEBIQUE ◦ SYSTEM◦
PLATE XII

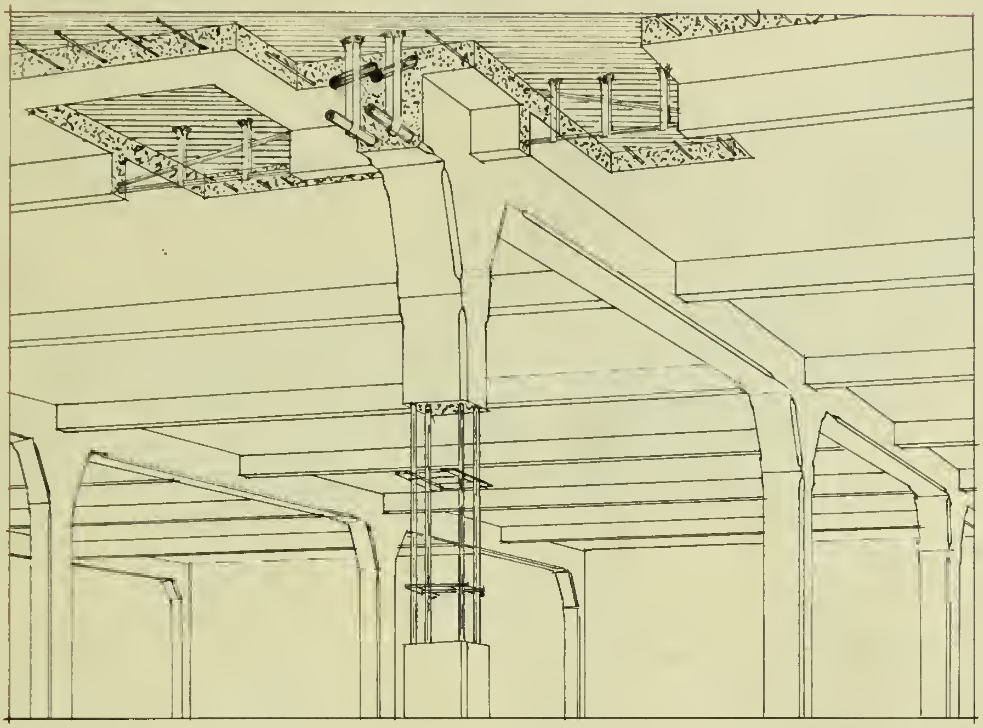


Fig 1

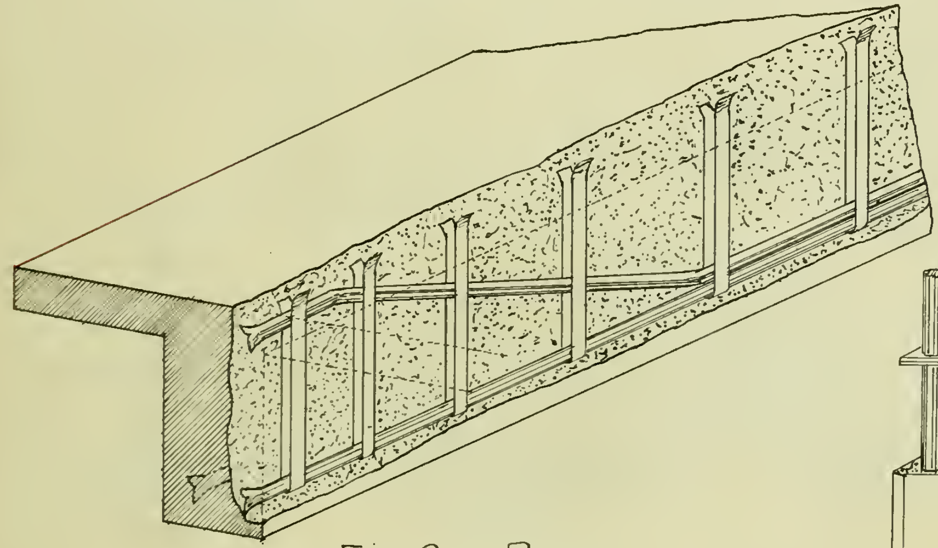
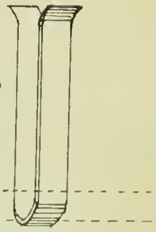


Fig. 2 Beam

Fig. 3



Stirrup

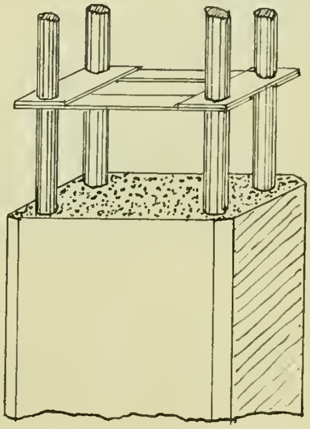


Fig 4 Column

·KAHN·SYSTEM·FLOREDOME+FLORETYLE·

PLATE XIII

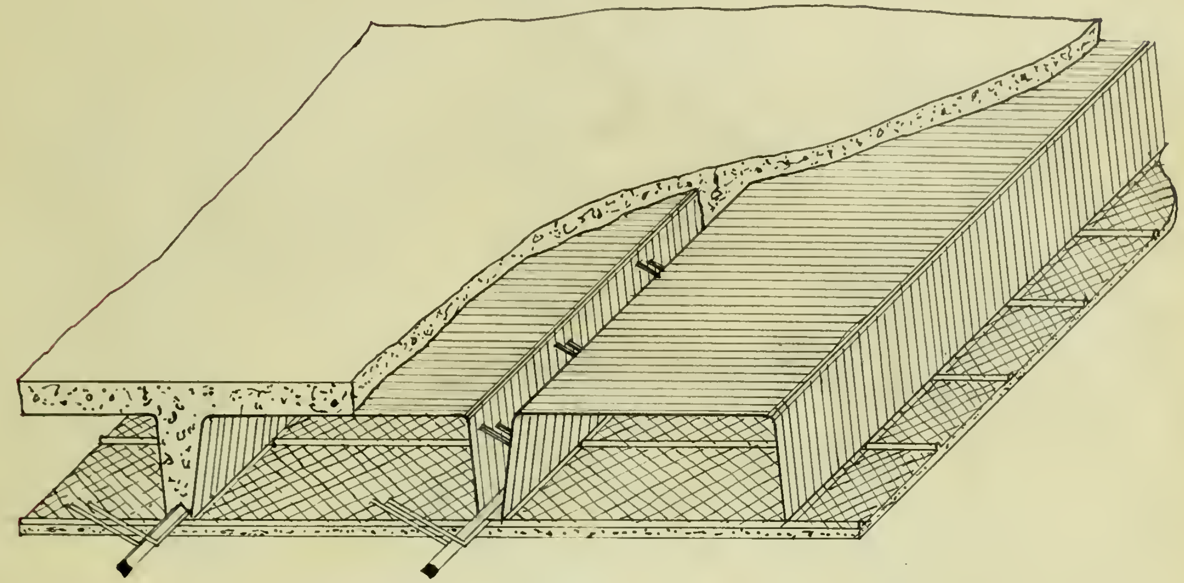


Fig. 1 Floretyles

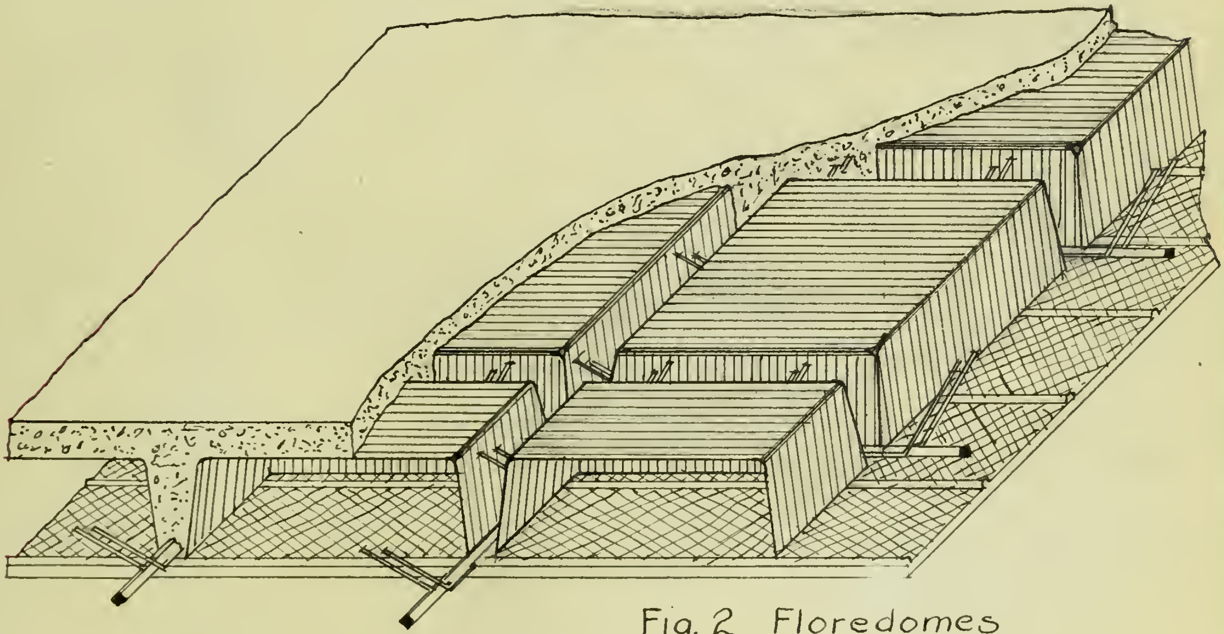


Fig. 2 Floredomes

Fig. 3 Kahn Bar

MERRICK • SYSTEM •

PLATE XIV

Fig. 1

Scale 1/8" = 1'-0"

Fig 2

Scale 1" = 2'-0"

◦ CONCRETE ◦ STEEL ◦ CO. ◦ SYSTEM ◦ M ◦

PLATE XV

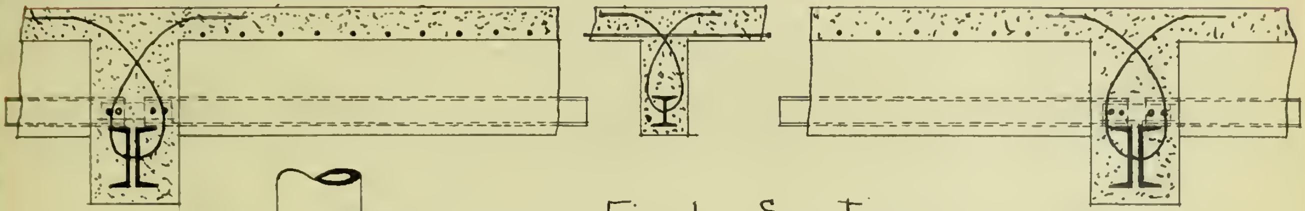


Fig 1 Section

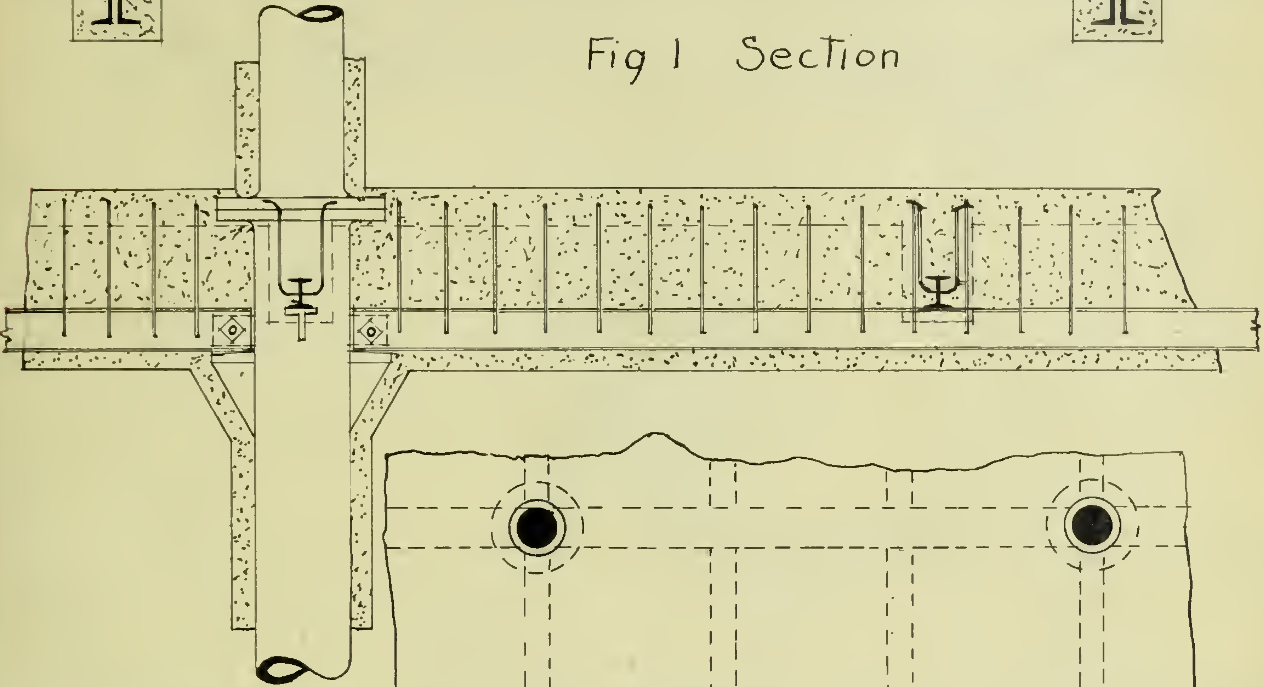


Fig. 2

Column Connection

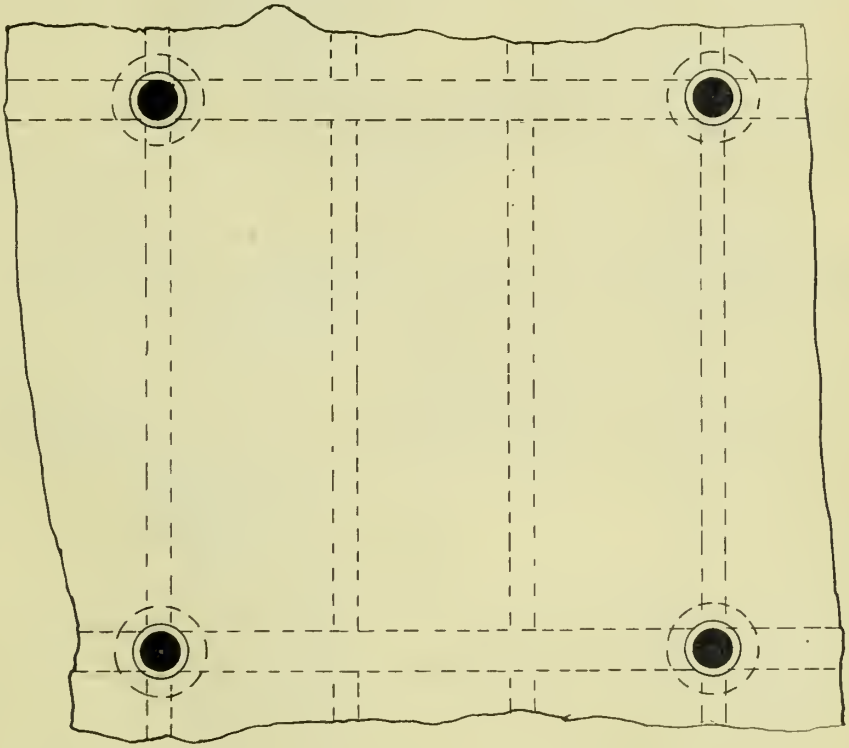


Fig 3 Plan

•WILSON • SYSTEM•

PLATE XVI

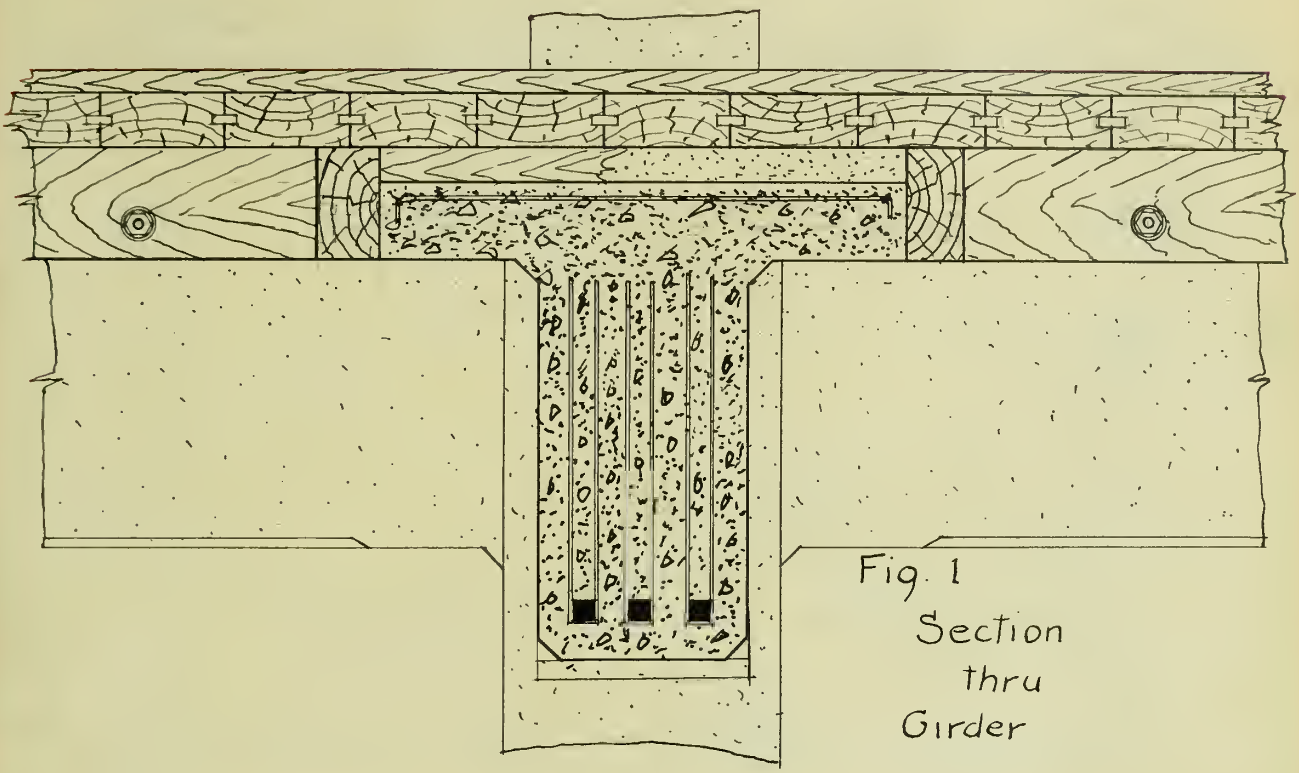


Fig. 1
Section
thru
Girder

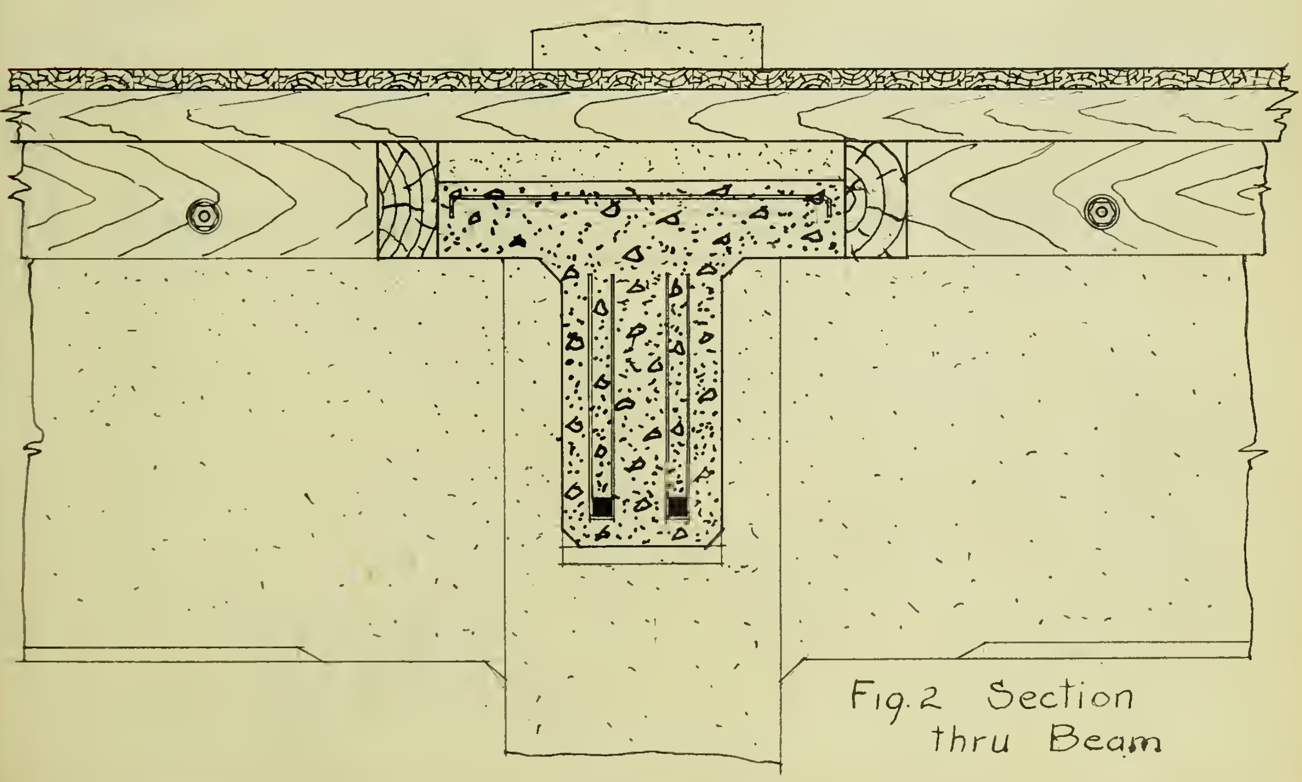


Fig. 2 Section
thru Beam

◦ COLUMBIAN ◦ SYSTEM ◦

PLATE XVII

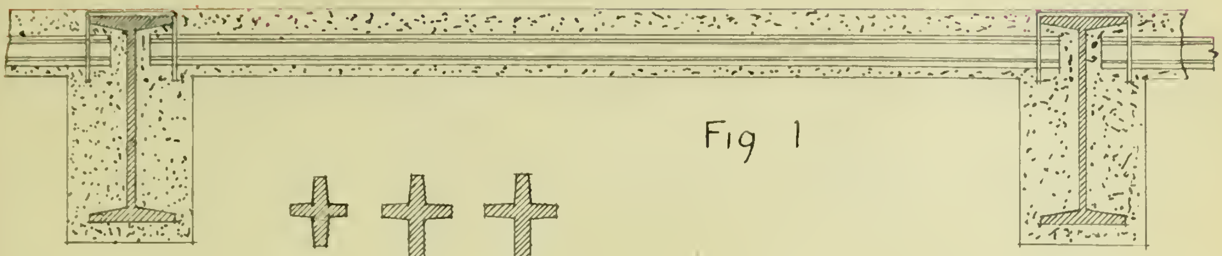


Fig 1

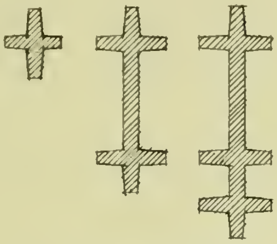


Fig 3 Bars

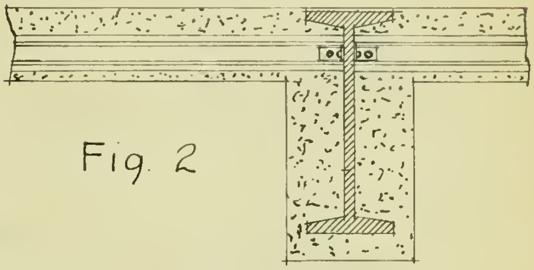


Fig. 2

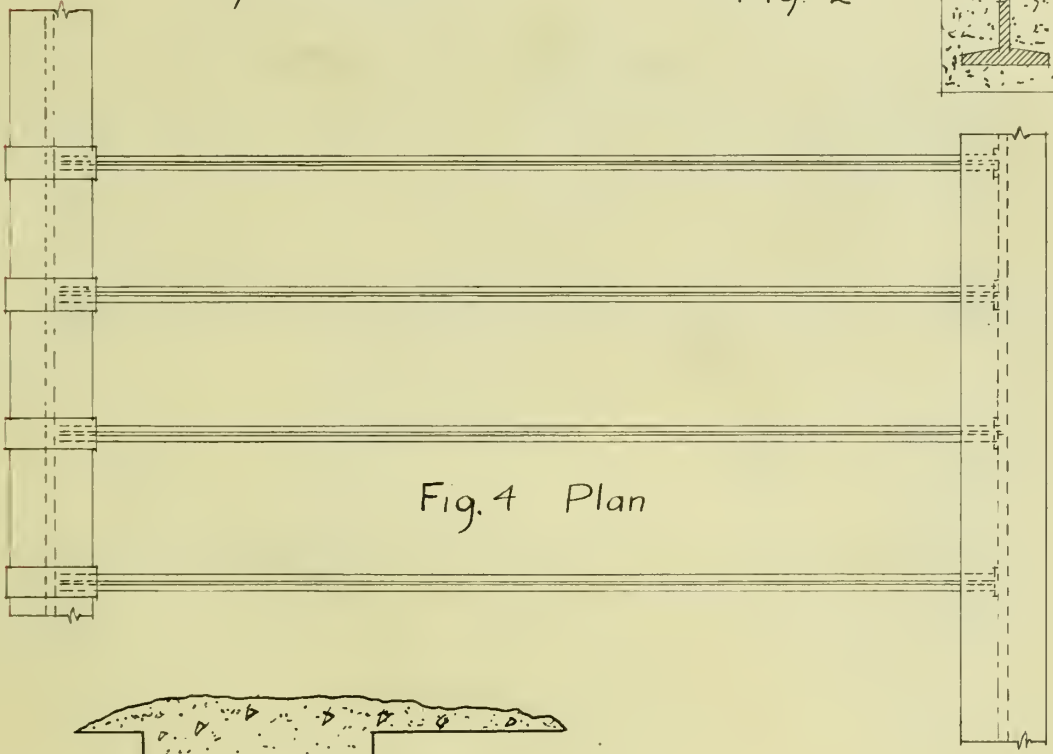


Fig. 4 Plan

Fig. 5
Beam Section

• MATRAI • SYSTEM •
PLATE XVIII

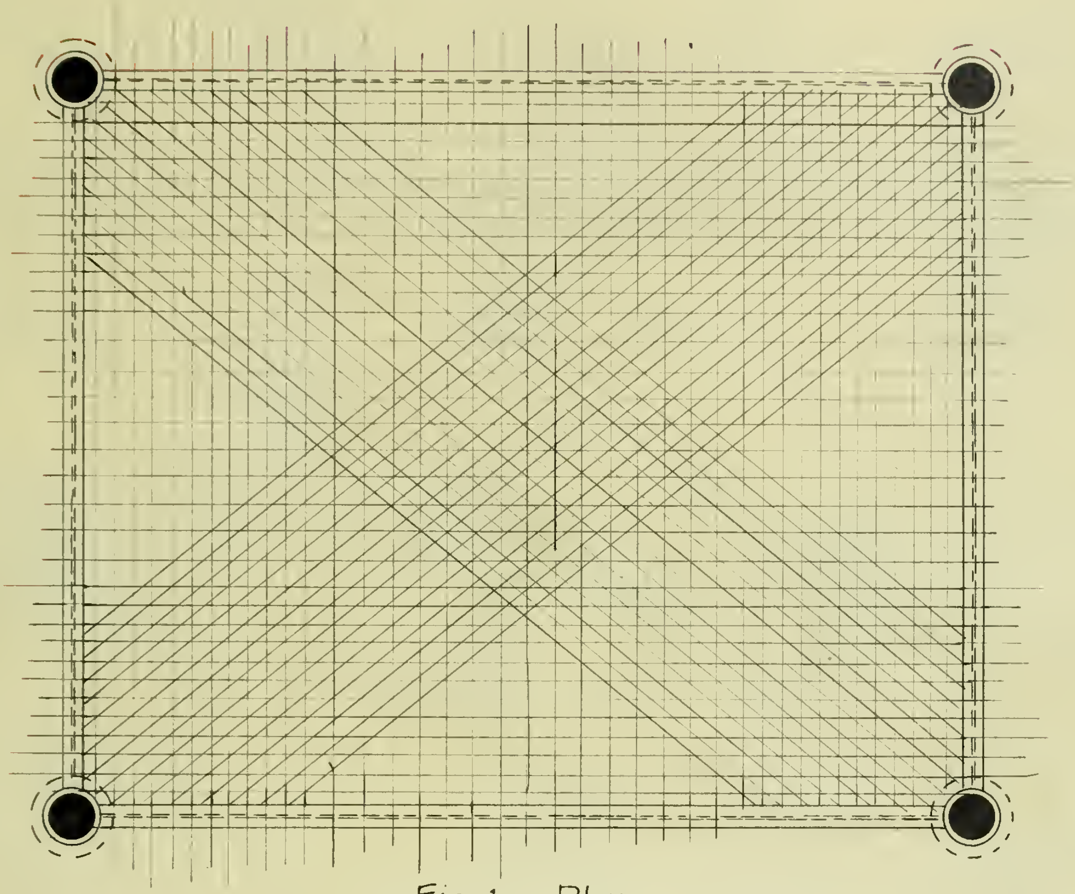


Fig. 1 Plan

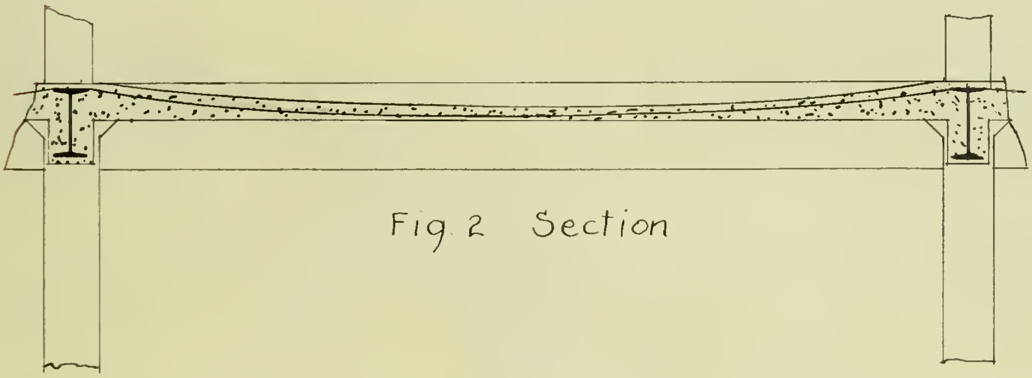


Fig. 2 Section

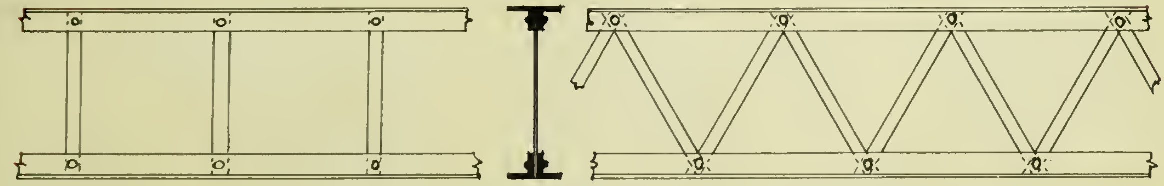


Fig 3 Girder Reinforcement

·METROPOLITAN·SYSTEM·

PLATE XIX

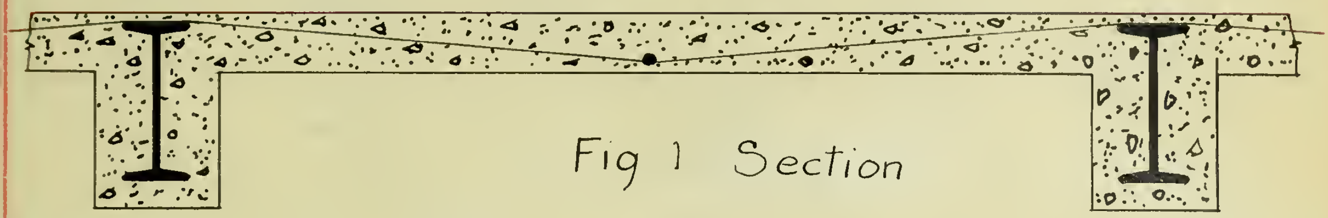


Fig 1 Section

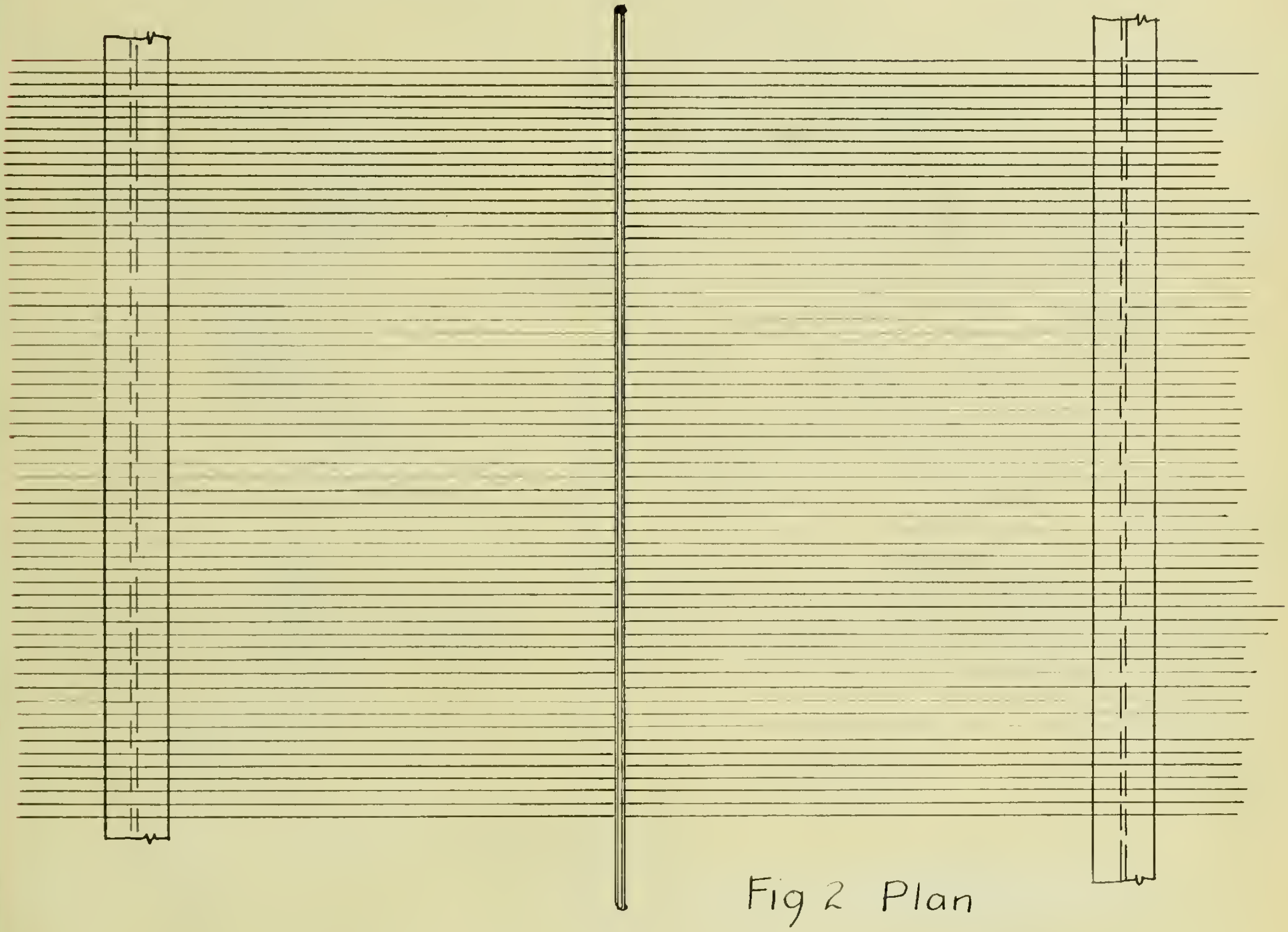


Fig 2 Plan

ROEBLING SYSTEM
PLATE XX

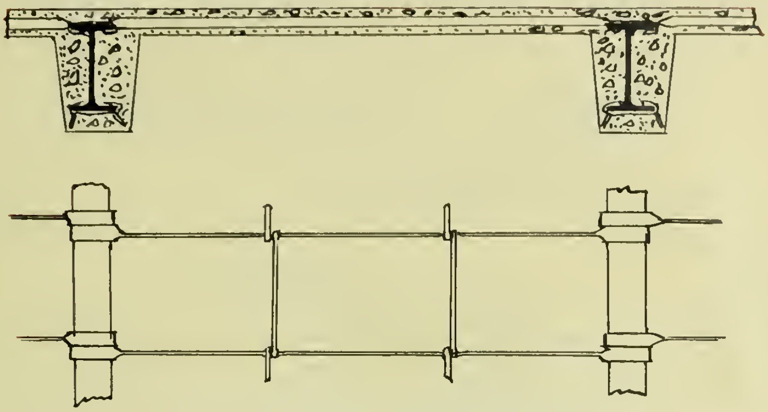


Fig 1. Ordinary Floor Slab

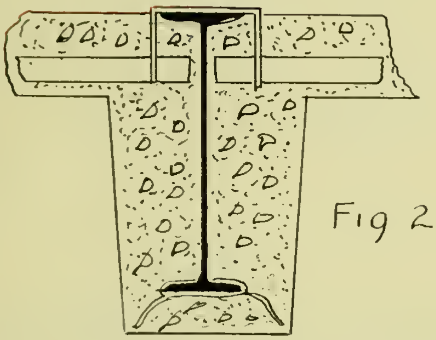


Fig 2

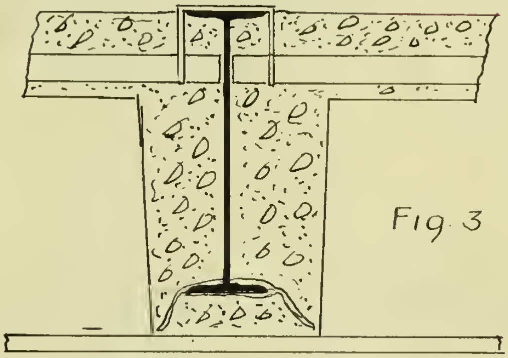


Fig. 3

Methods of Attaching Reinforcement to Beam

Fig. 4

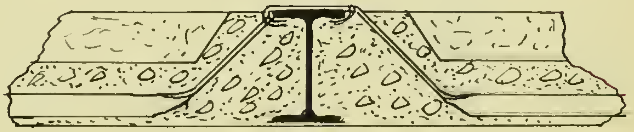


Fig 5

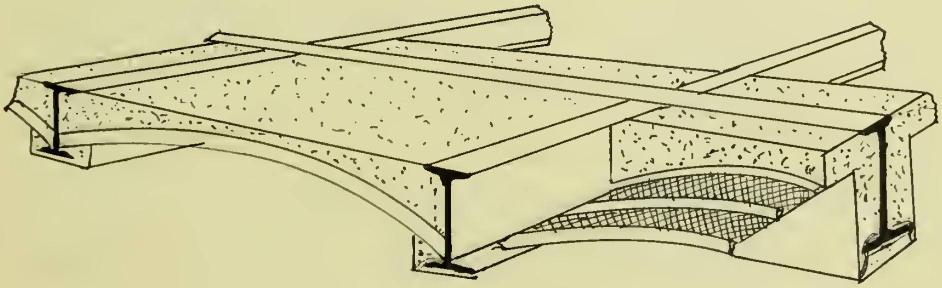


Fig 6 Arch Construction

∘ WHITE ∘ ∘ SYSTEM ∘

PLATE XXI

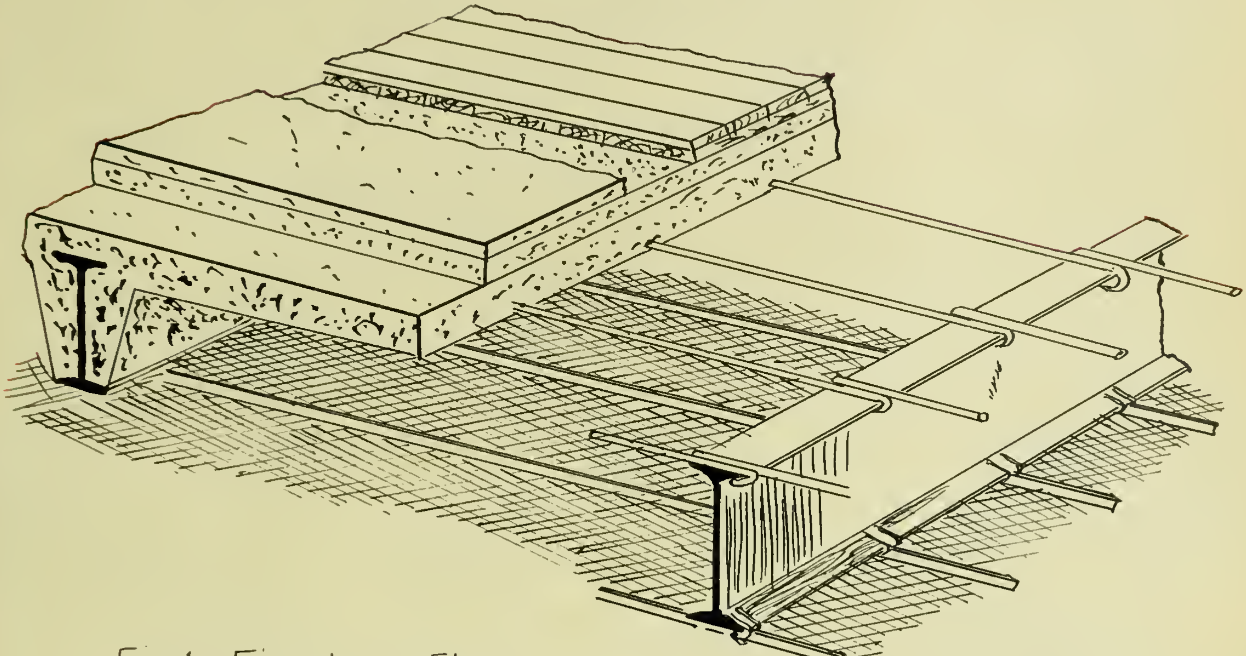


Fig. 1 Finished Floor

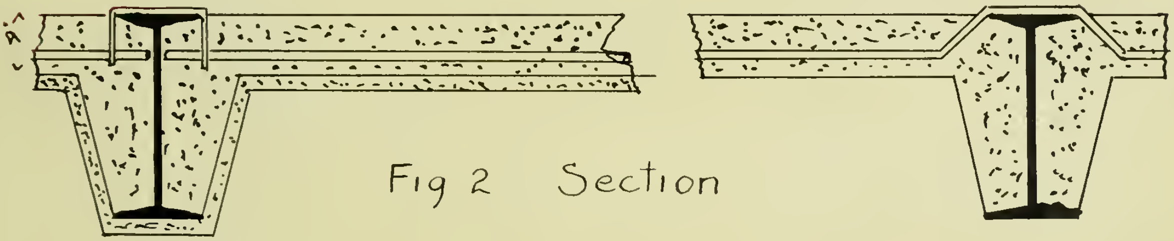


Fig 2 Section

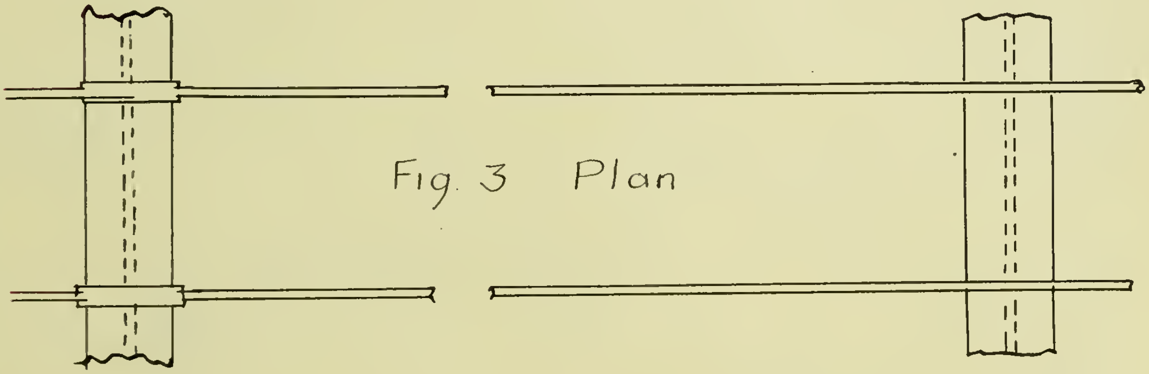
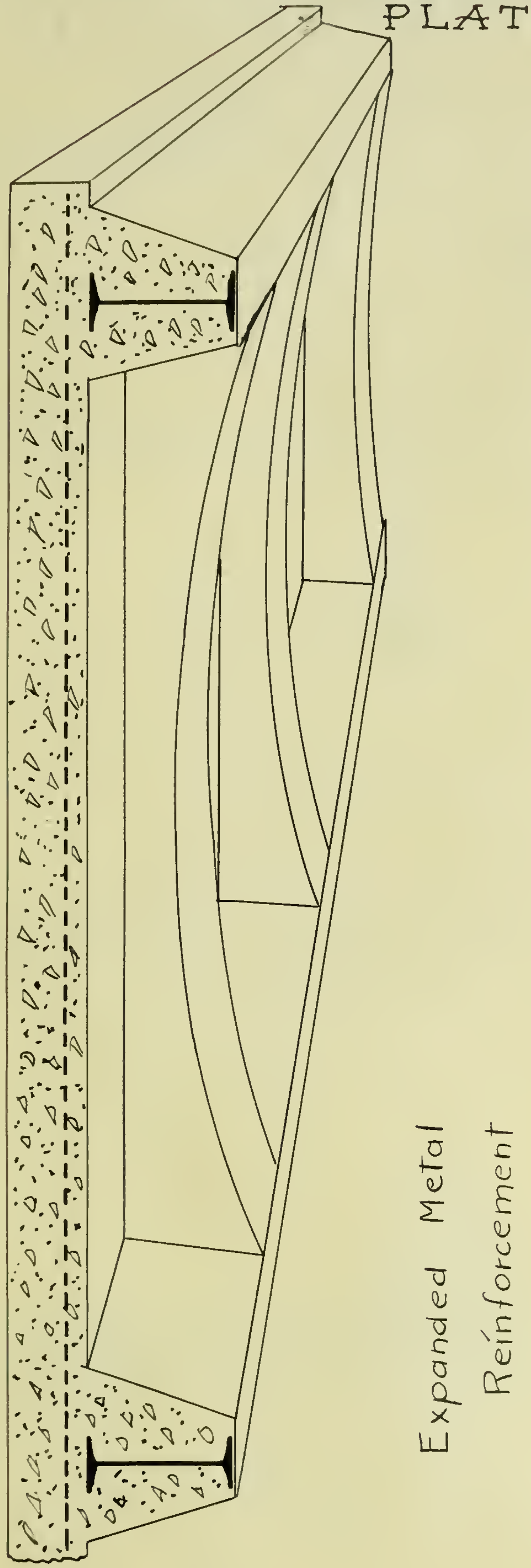


Fig. 3 Plan

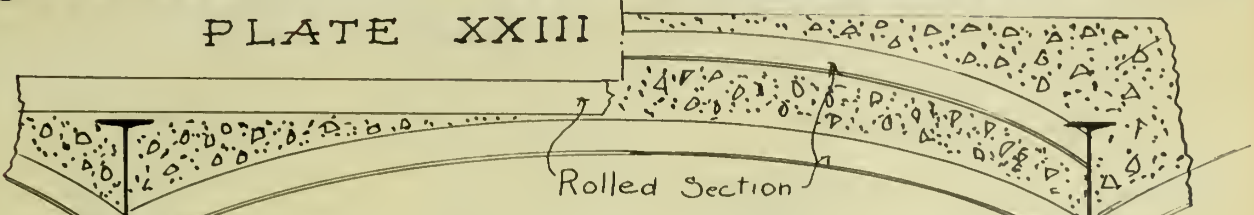
·GOLDING·RIBBED·FLOOR·ARCH·

PLATE XXII



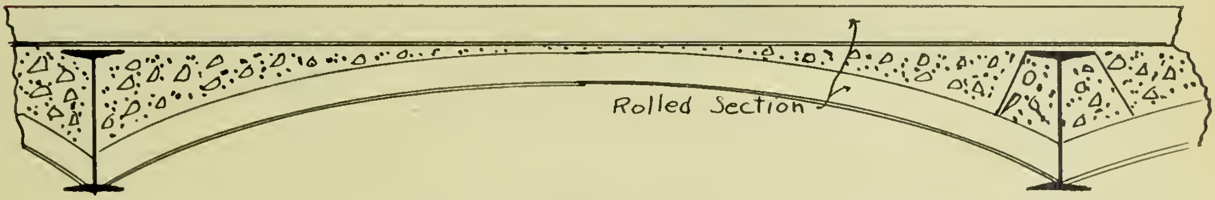
• SYSTEMS • WITH • ARCHES • ROLLED • SECTIONS

PLATE XXIII



Single Double

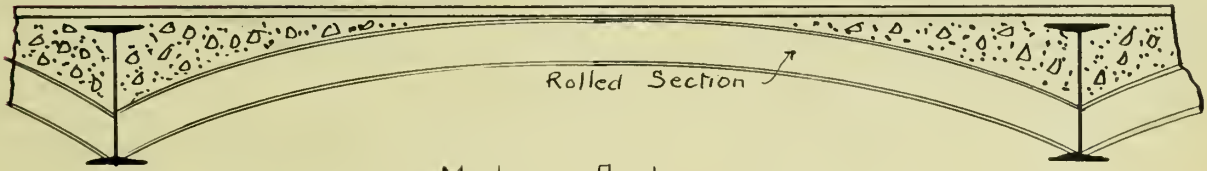
Fig 1



Flat Top

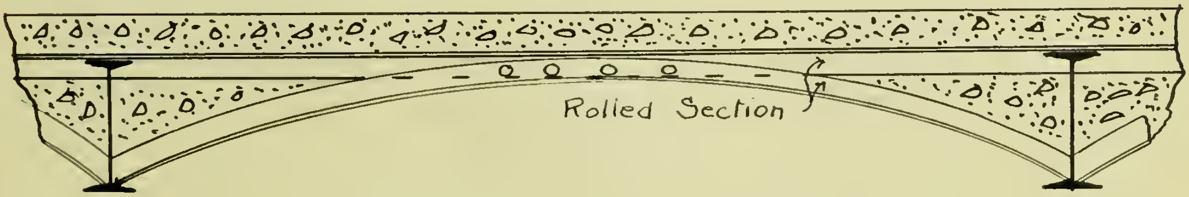
Fig 2

Monier Arch



Melan Arch

Fig. 3



Wuench Arch

Fig 4

• SIEGWART • BEAM • SYSTEM •

PLATE XXIV

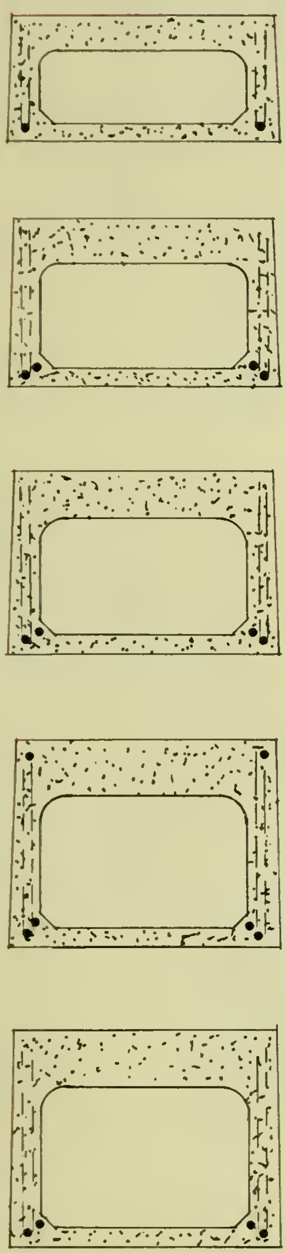


Fig. 1 Types of Sections

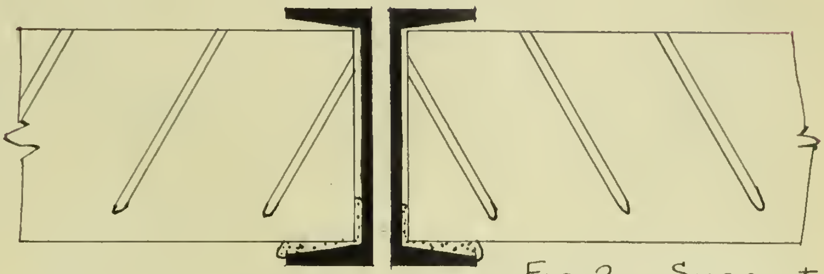


Fig 2 Support

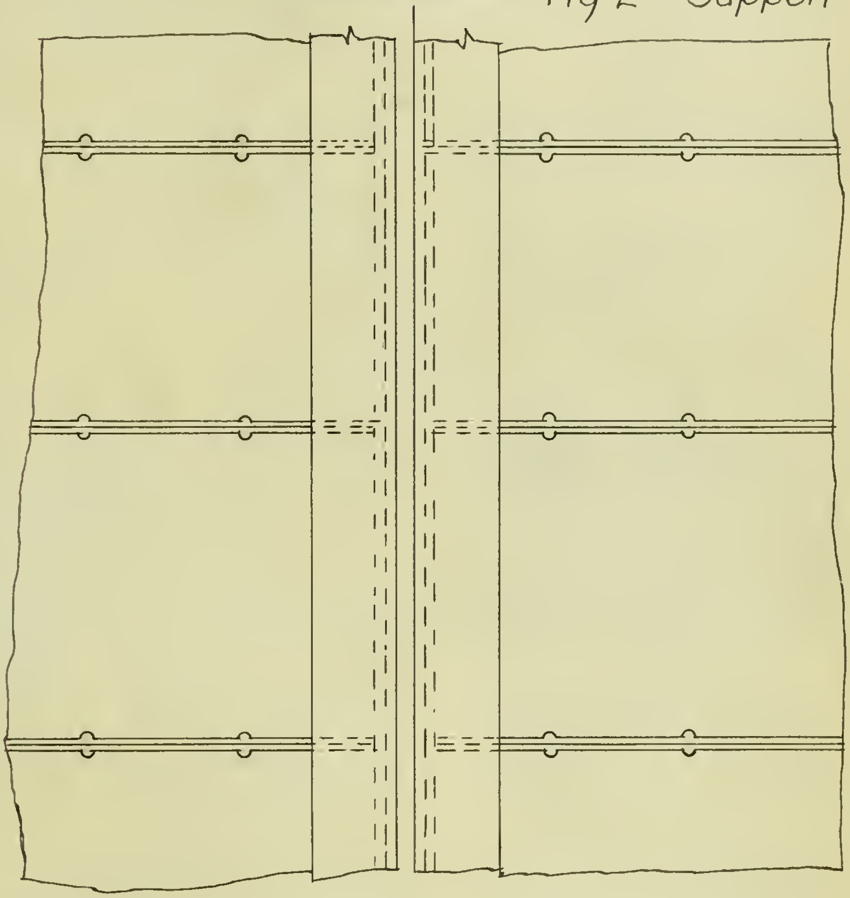


Fig 3 Plan

◦UNIT◦BILT◦SYSTEM◦

PLATE XXV

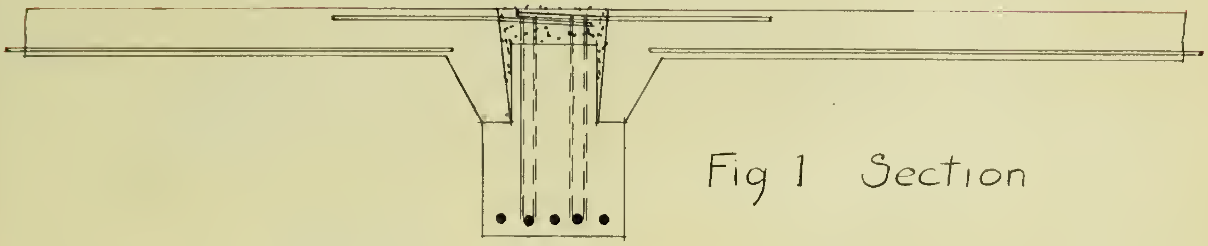


Fig 1 Section

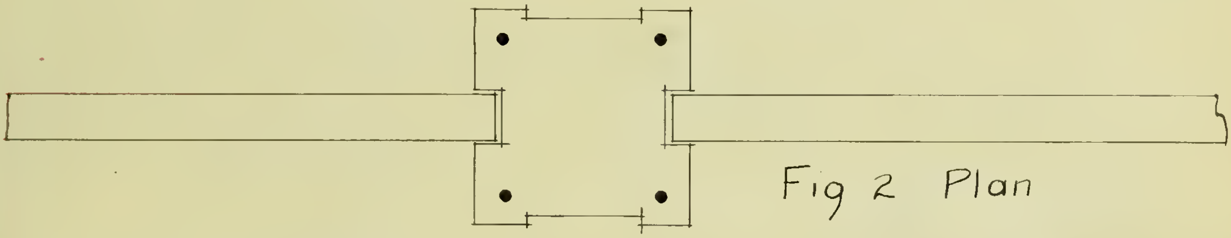


Fig 2 Plan

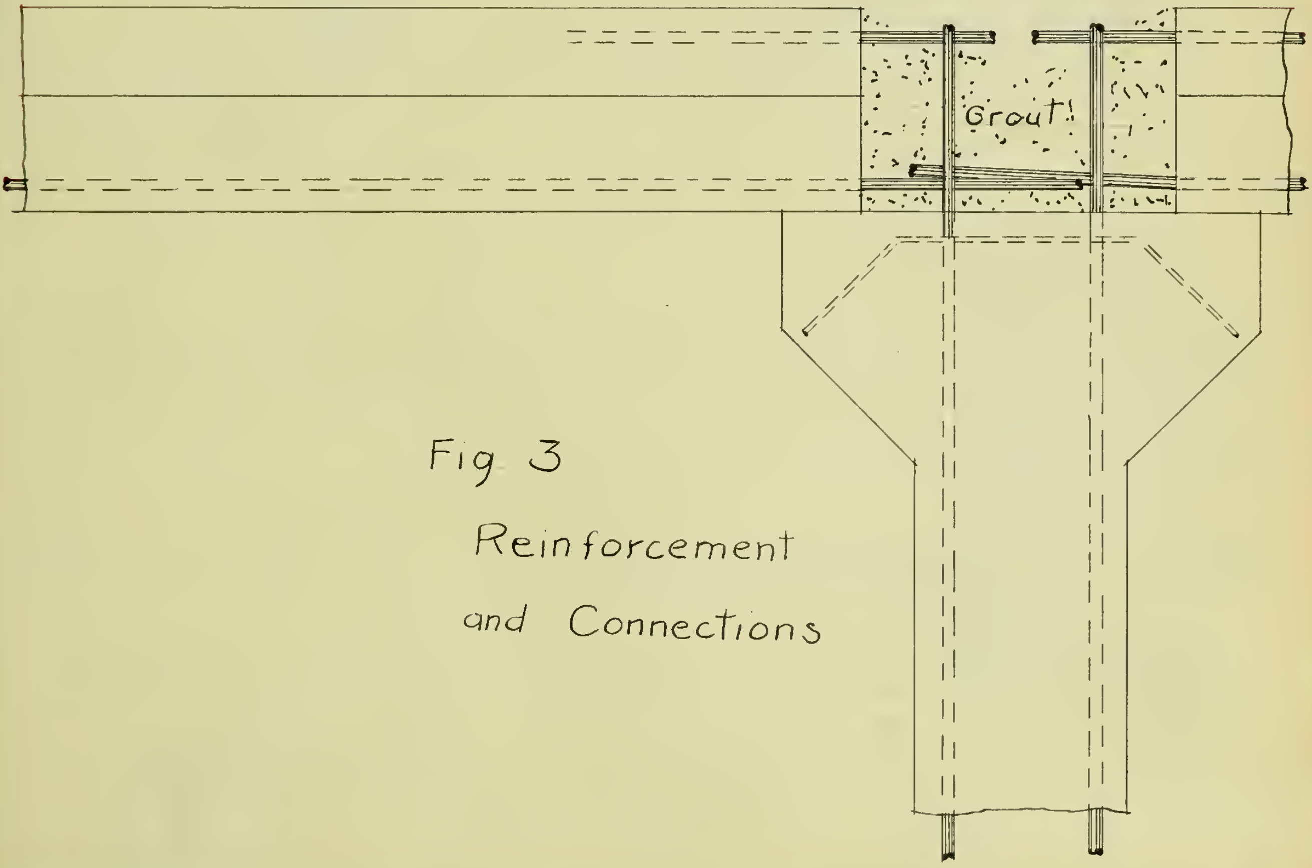


Fig 3

Reinforcement and Connections

•VAUGHAN • SYSTEM•

PLATE XXVI

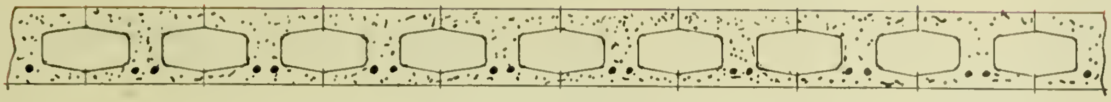


Fig 1 Floor Construction

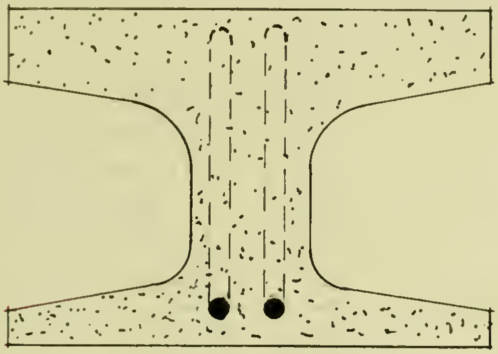


Fig. 2 Single Beam

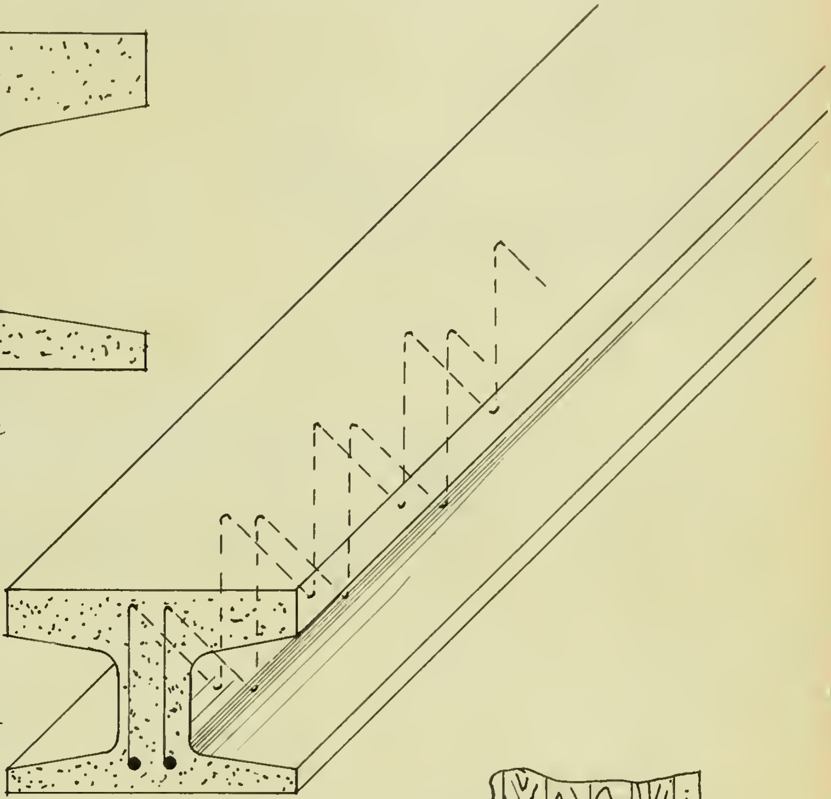


Fig. 3 Web Reinforcement

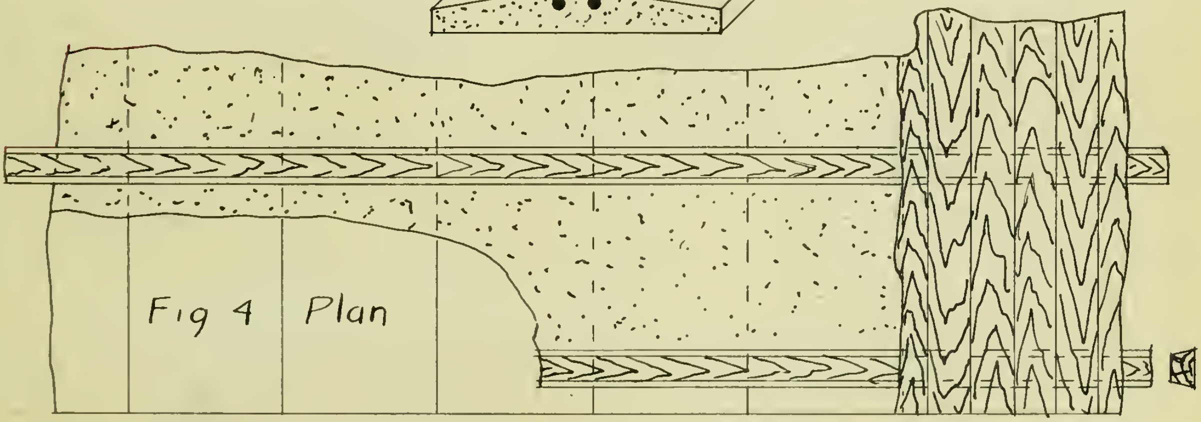


Fig 4 Plan

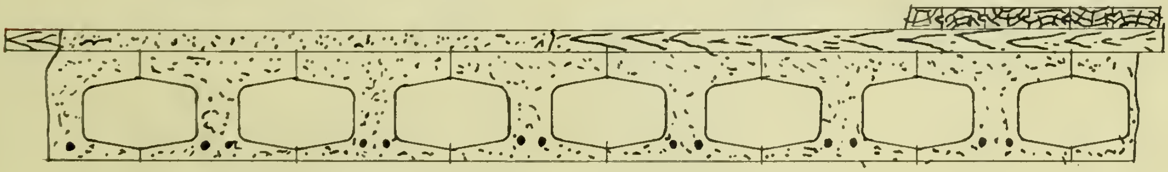


Fig 5 Complete Floor

∘VISINTINI∘ ∘SYSTEM∘

PLATE XXVII

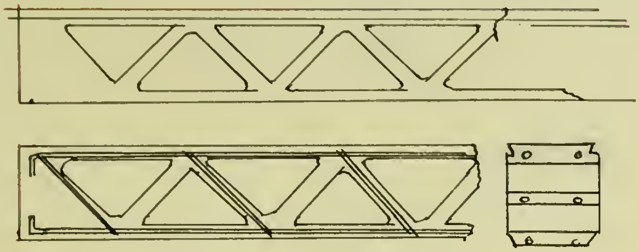


Fig. 1 Elevation and Section of Beam Warren Truss Type

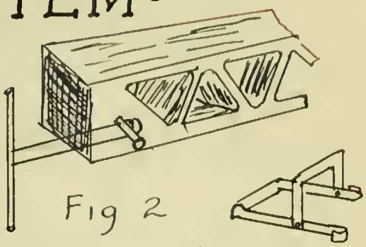


Fig 2

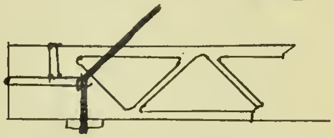


Fig. 3 Method of tying to wall and lifting beams

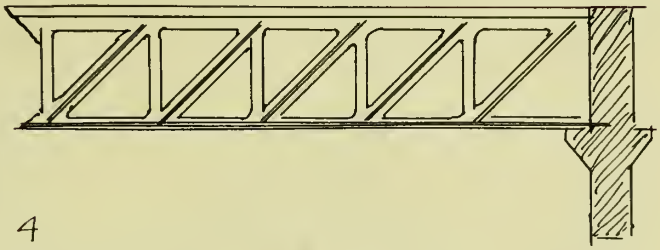


Fig. 4 Section of a Girder Pratt Truss Type

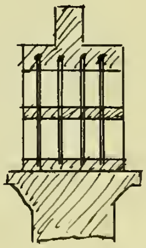
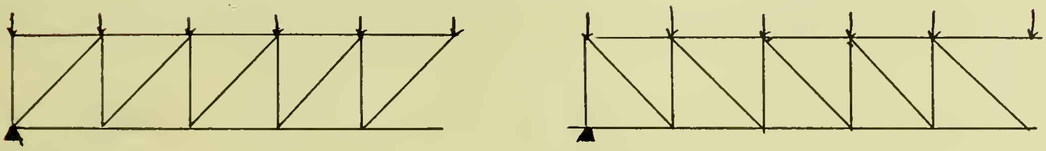


Fig. 5 Stress Diagrams for Analysis



CORR TILE FLOOR SYSTEMS

PLATE XXVIII

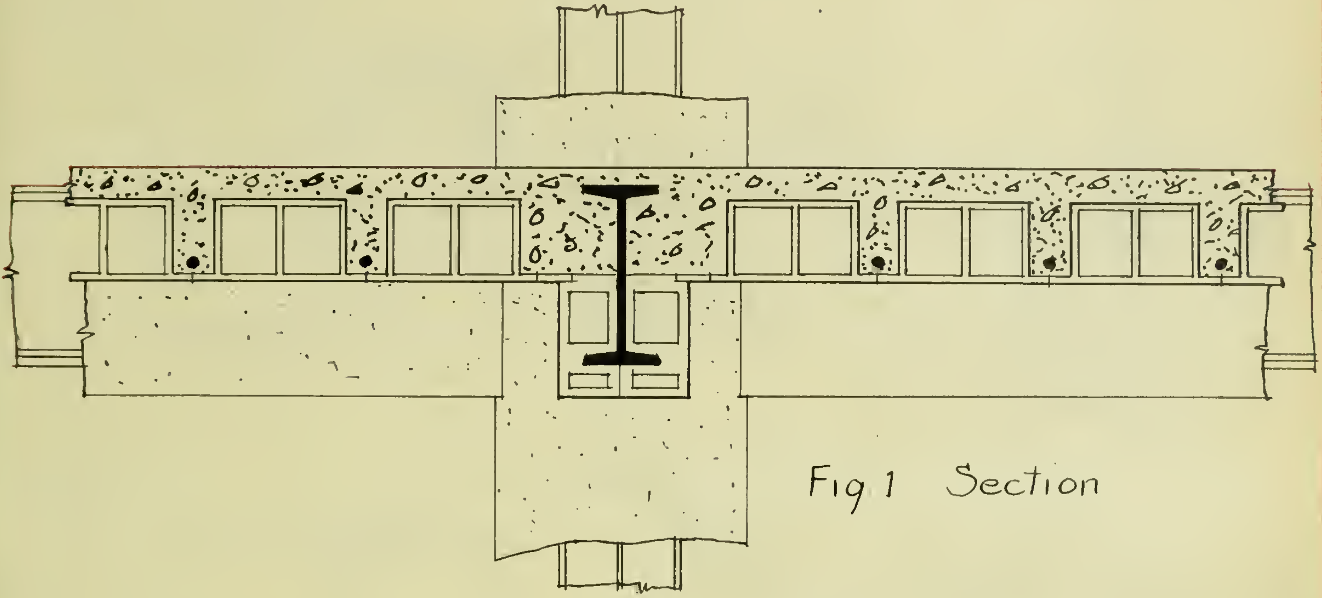


Fig 1 Section

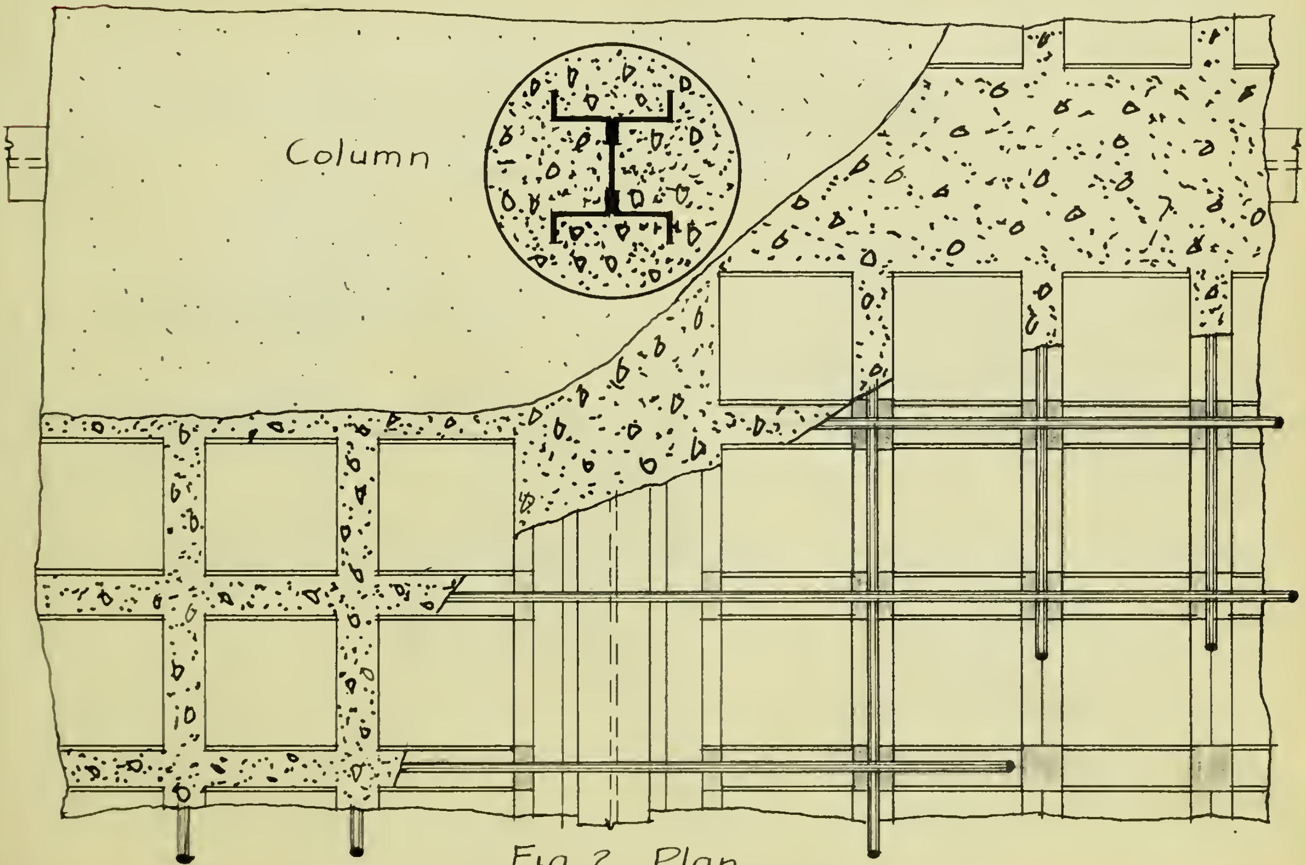


Fig 2 Plan

∘CORR∘TILE∘FLOOR∘SYSTEMS∘

PLATE XXIX

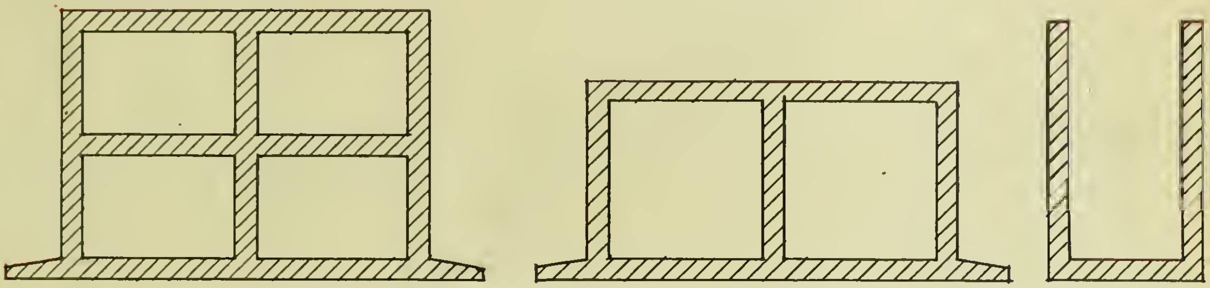


Fig. 1 System A

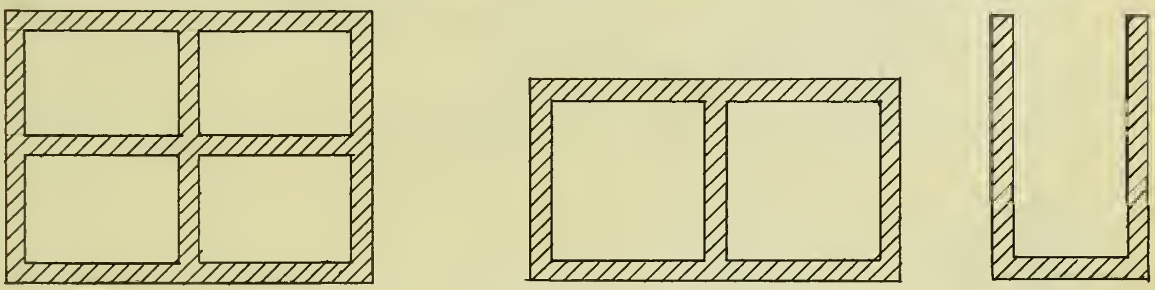


Fig. 2 System B

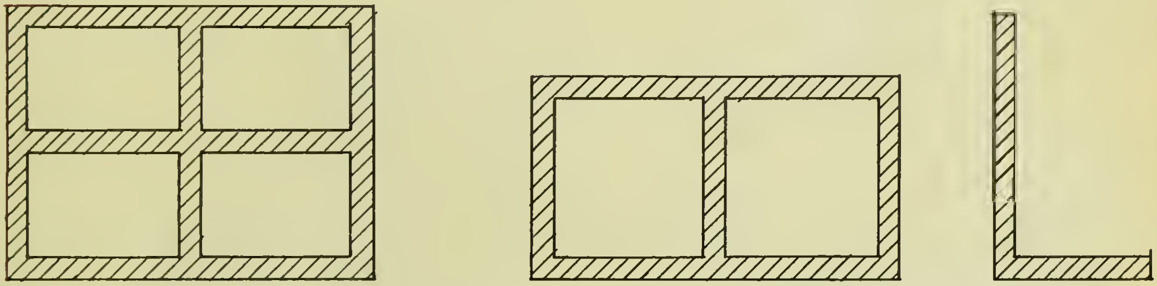


Fig. System C

◦FAWCETT◦ ◦SYSTEM◦

PLATE XXX

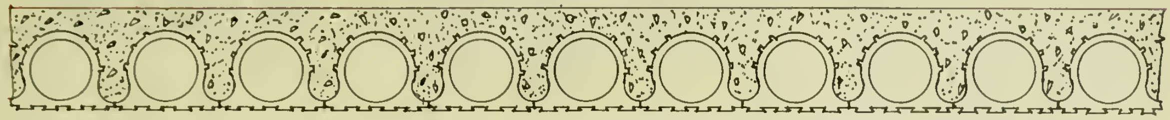


Fig. 1 Section between Beams

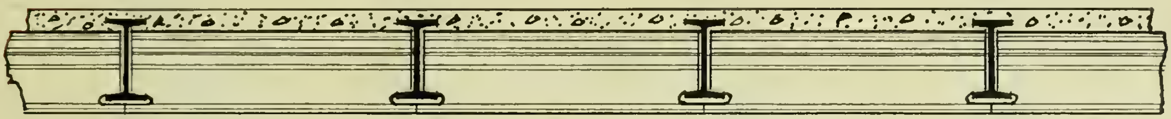


Fig 2 Section across Beams

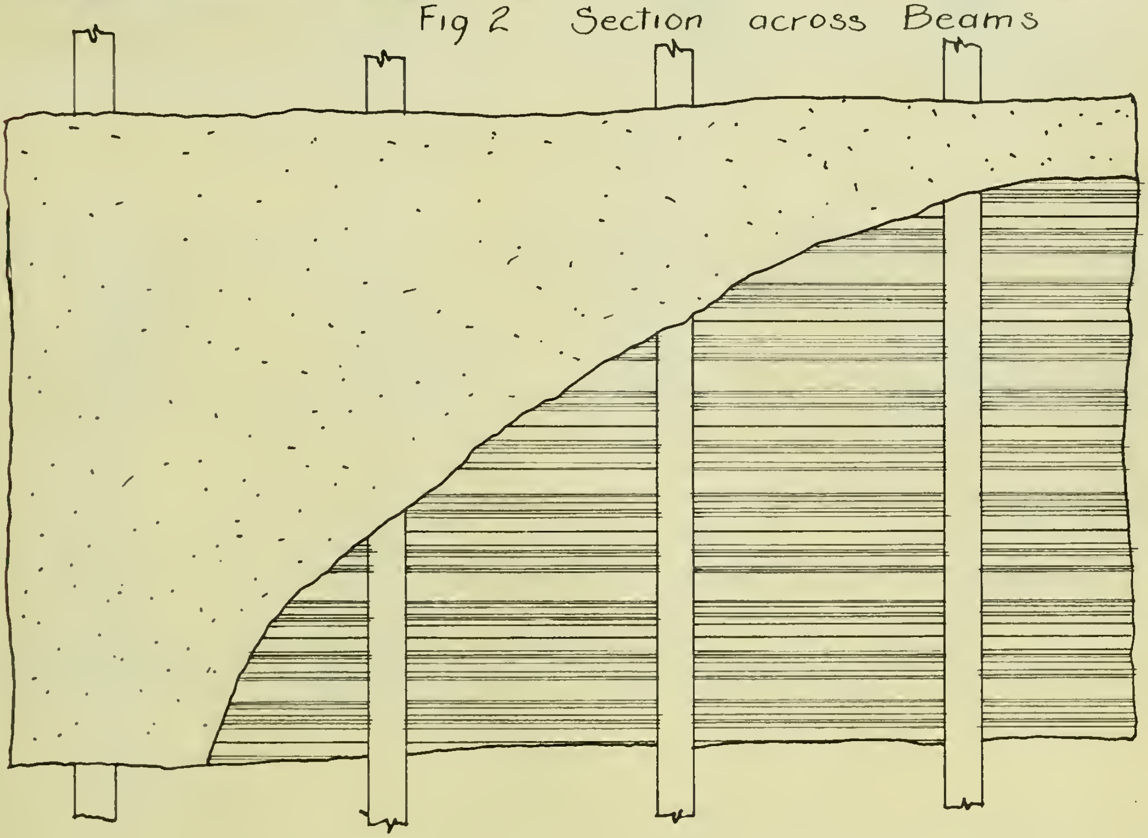
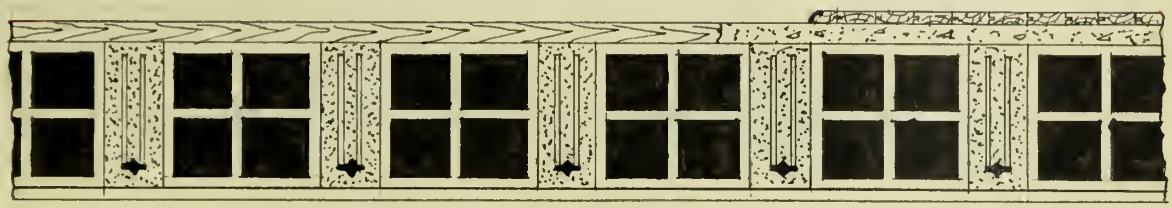


Fig 3 Plan

·KAHN·SYSTEM·ONE·WAY·TILE·

PLATE XXXI

Fig 1 Section



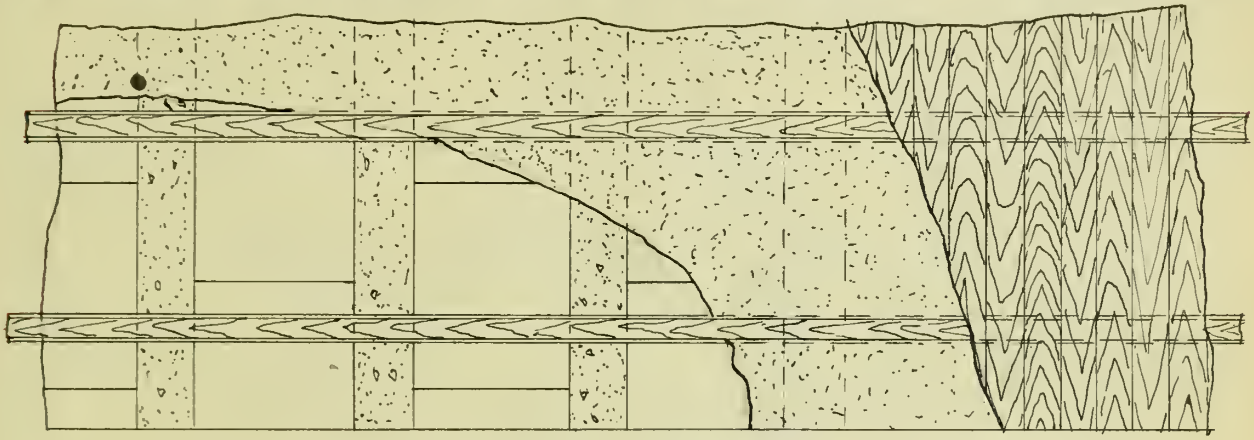


Fig. 2 Plan

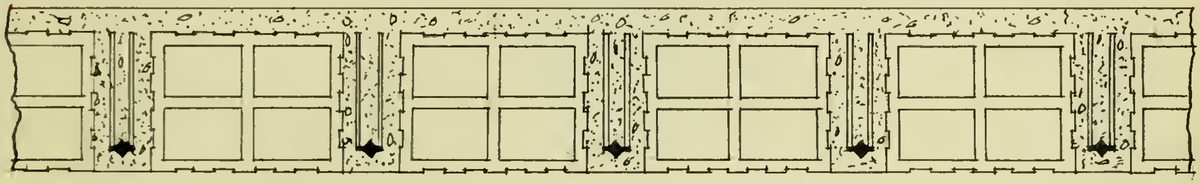


Fig 3 Cross Section

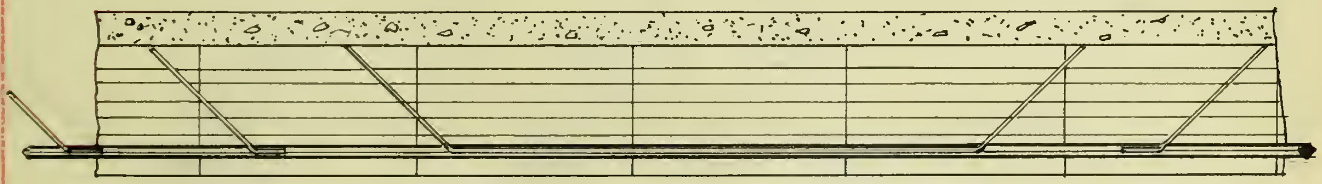


Fig. 4 Longitudinal Section

•JOHNSON•SYSTEM•

PLATE XXXII

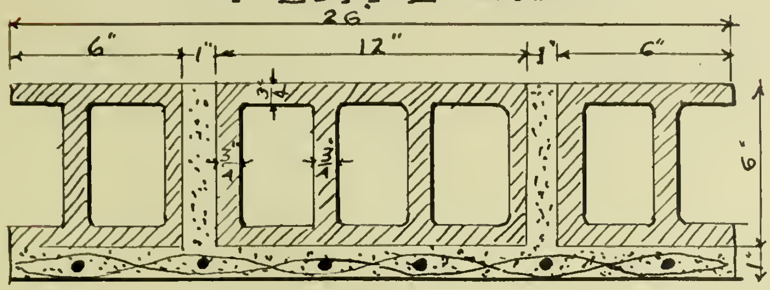


Fig. 1 Type 1

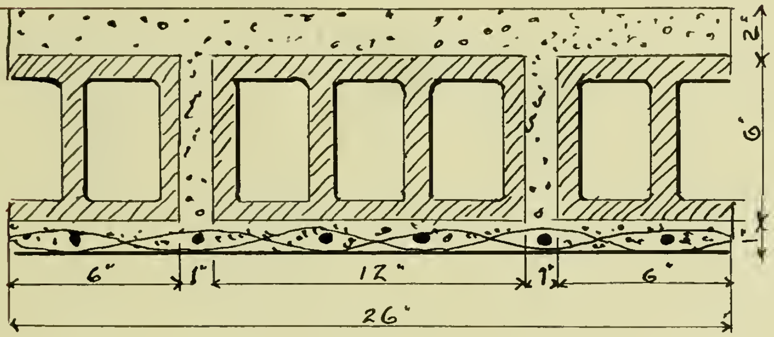


Fig. 2 Type 2

NOLAN TWO-WAY TILE SYSTEM

PLATE XXXIII

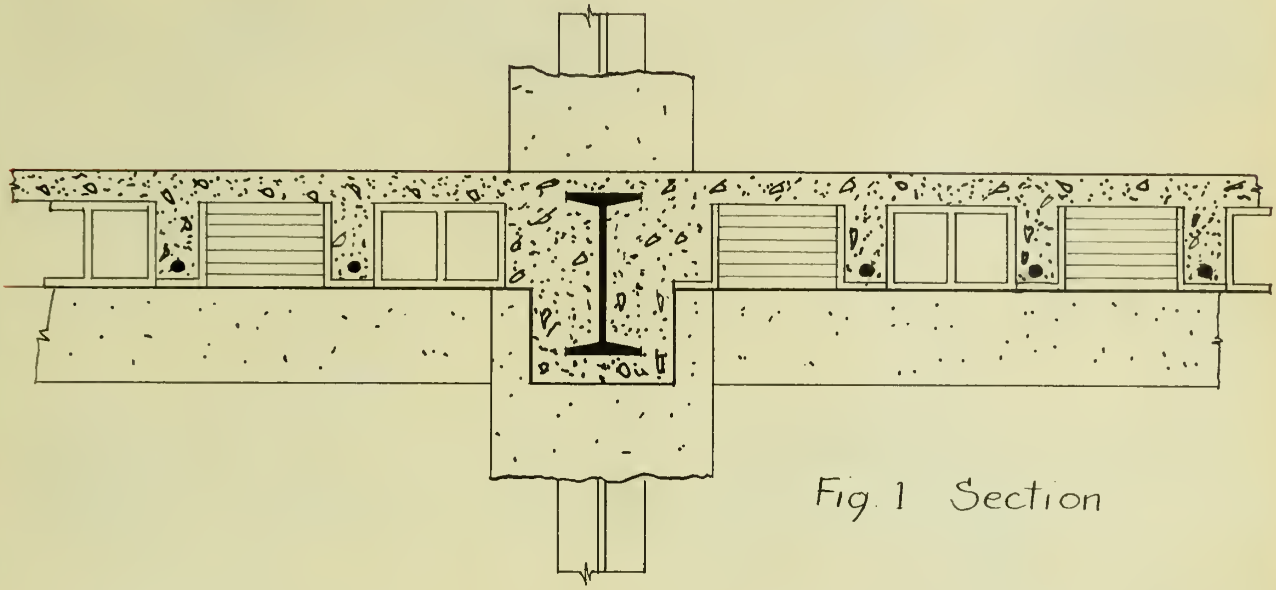


Fig. 1 Section

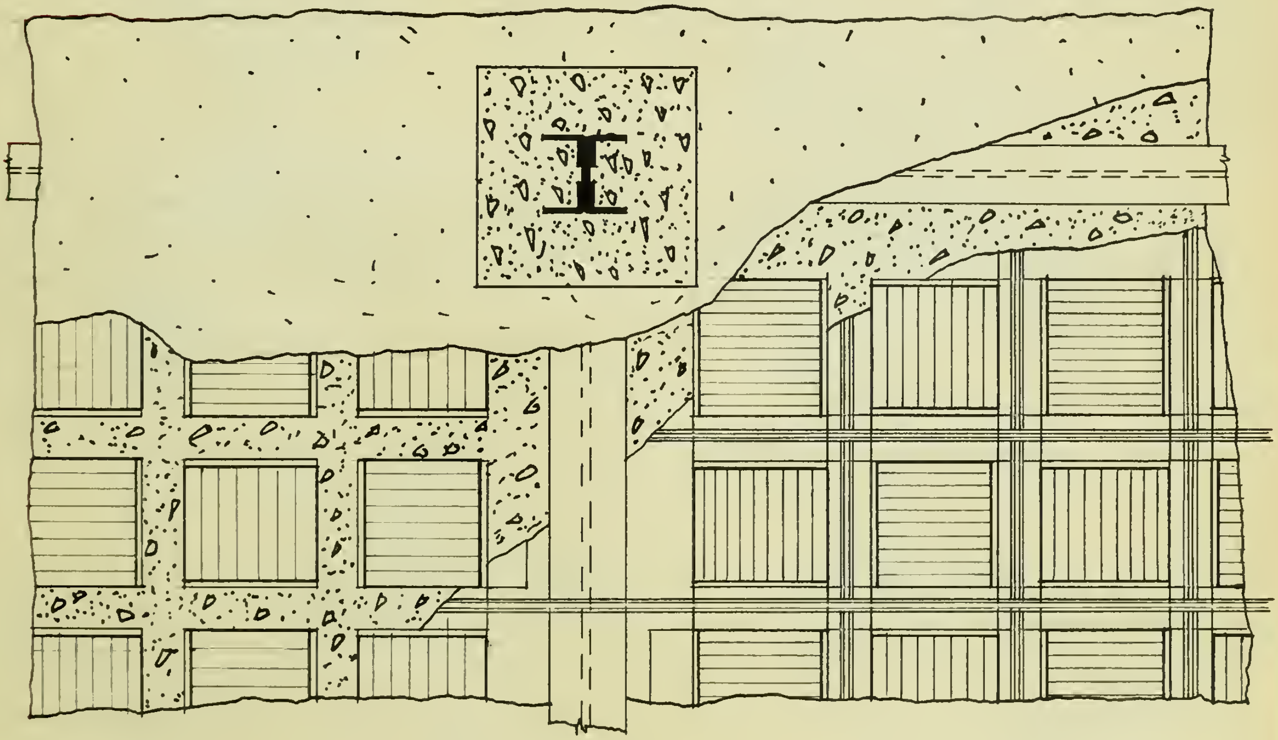


Fig 2 Plan

·SLABS·CONSTRUCTED·WITHOUT·CENTERING·

PLATE XXXIV

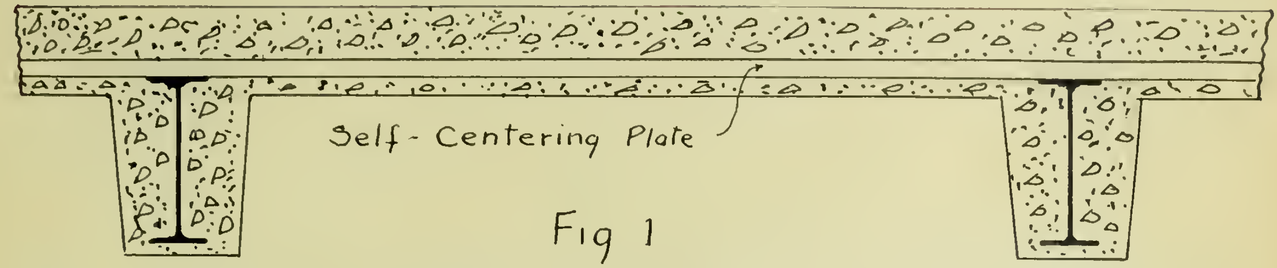


Fig 1

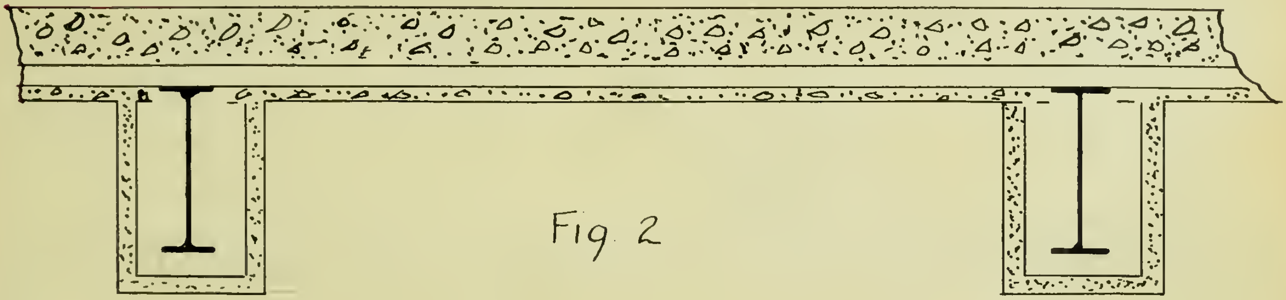


Fig. 2

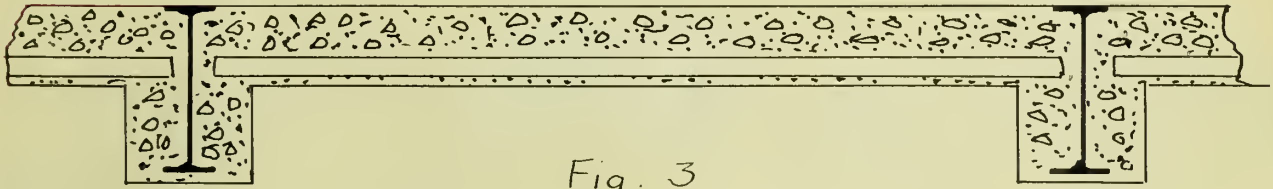


Fig. 3

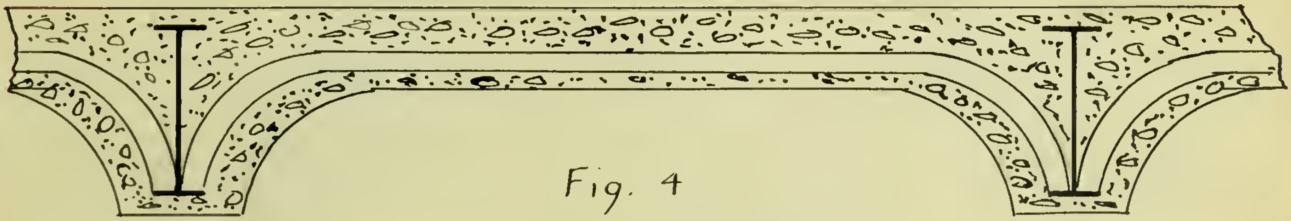


Fig. 4

·SLABS·CONSTRUCTED·WITHOUT·CENTERING·

PLATE XXXV

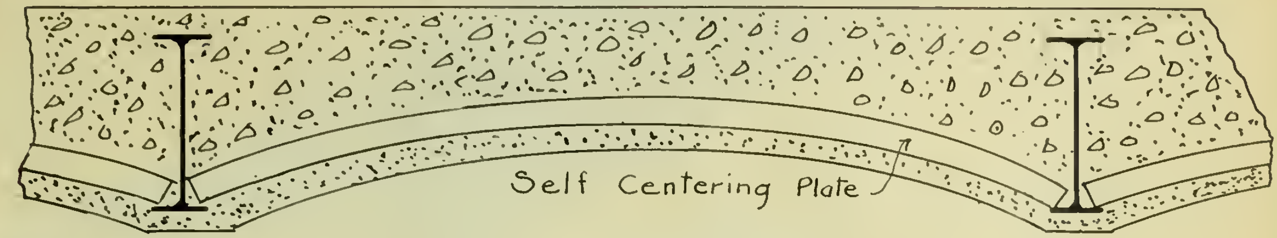


Fig 5

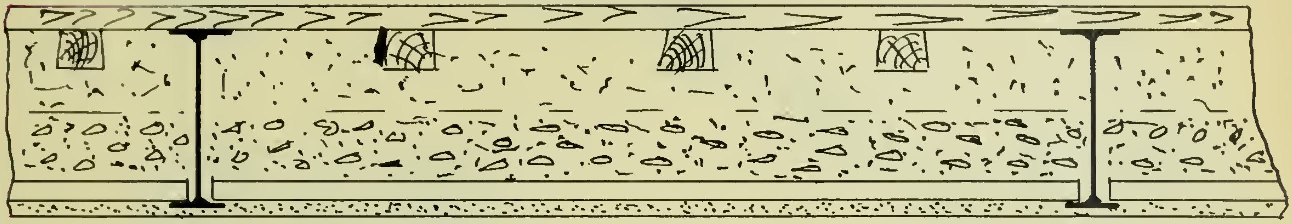


Fig 6

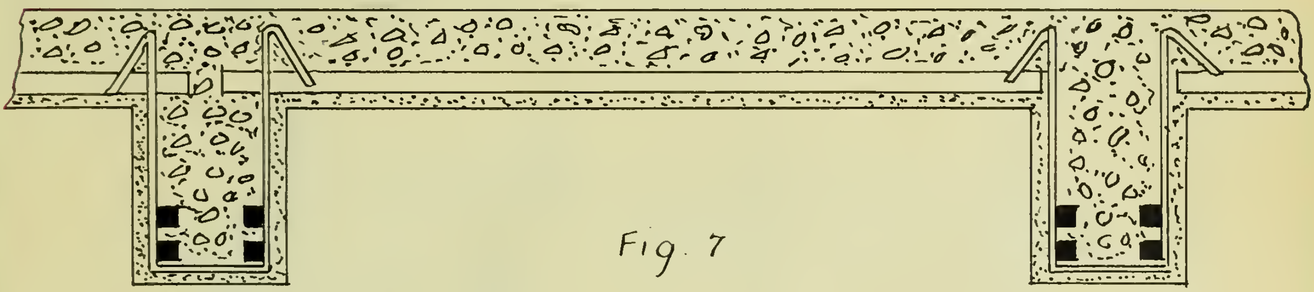


Fig. 7

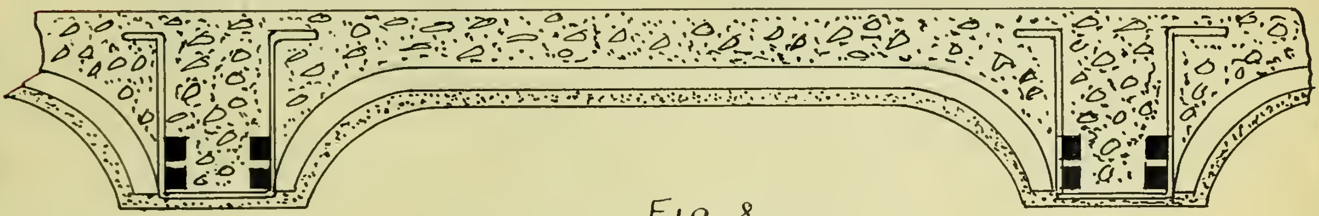


Fig. 8

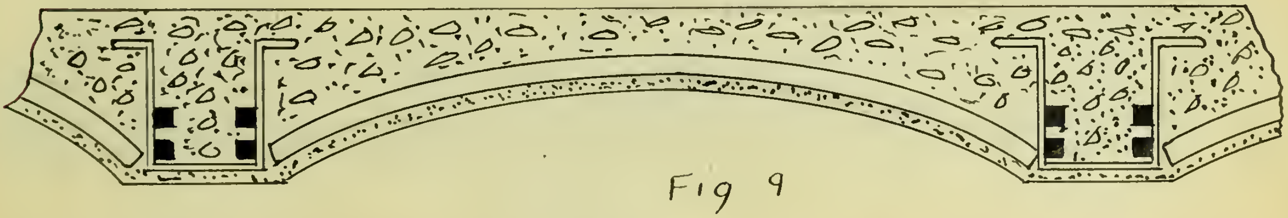


Fig 9

SELF-SUPPORTING METAL FABRIC

PLATE XXXVI

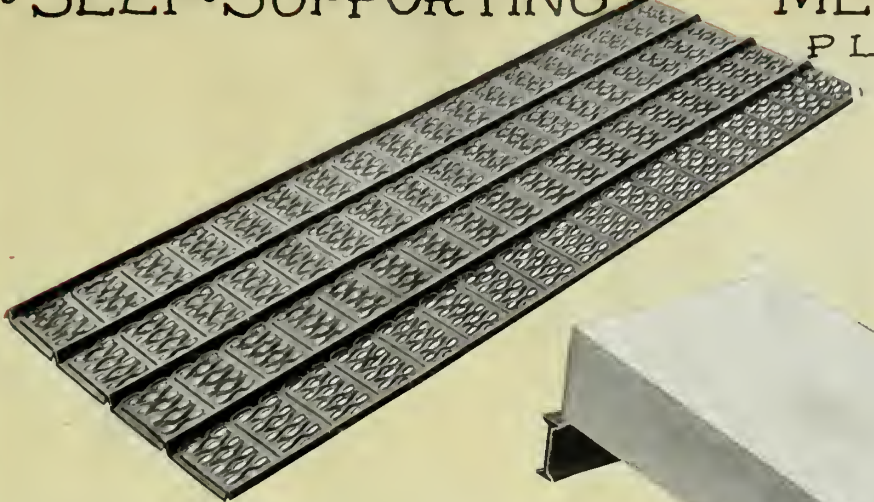


Fig. 1 Rib Truss

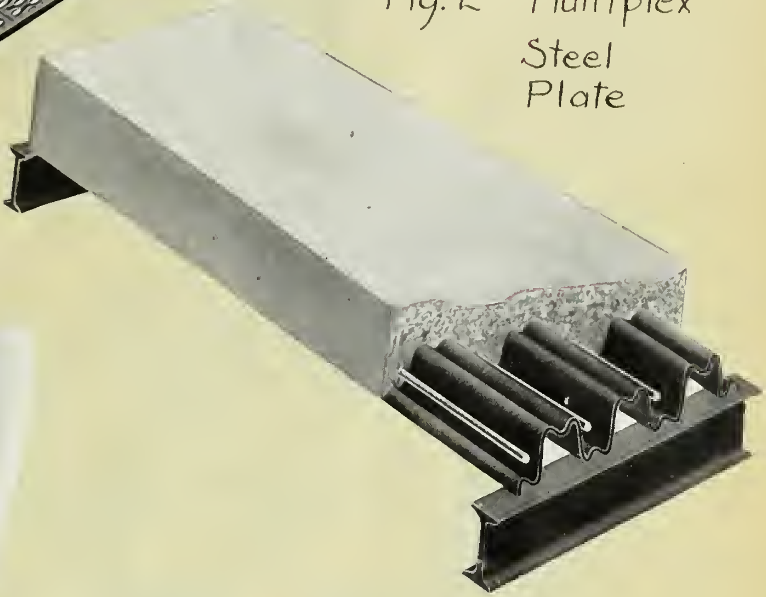


Fig. 2 Multiplex Steel Plate

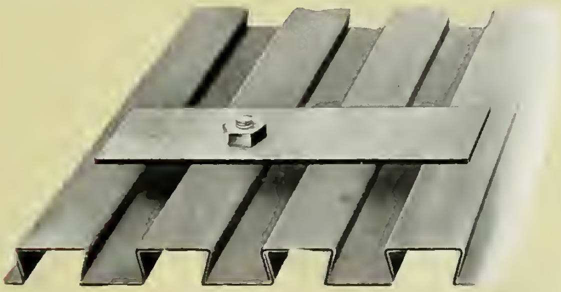


Fig. 3 Ferrolithic Plate

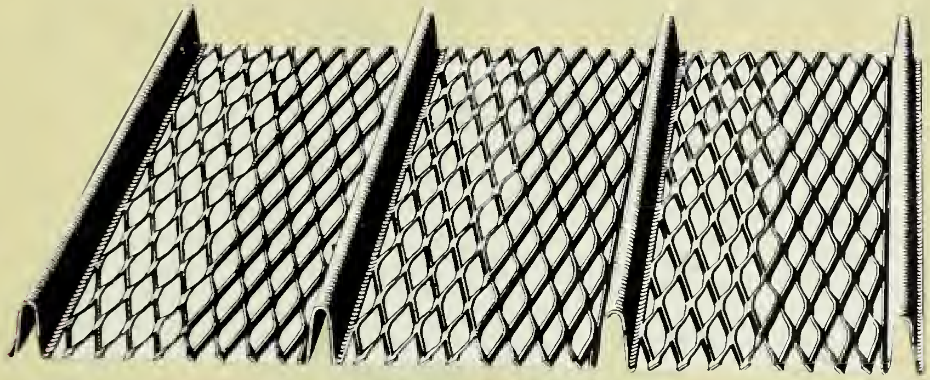


Fig. 4 Self-Sentering

Fig. 5 Hyrib

◦ SELF ◦ SUPPORTING ◦ METAL ◦ FABRIC ◦

PLATE XXXVII

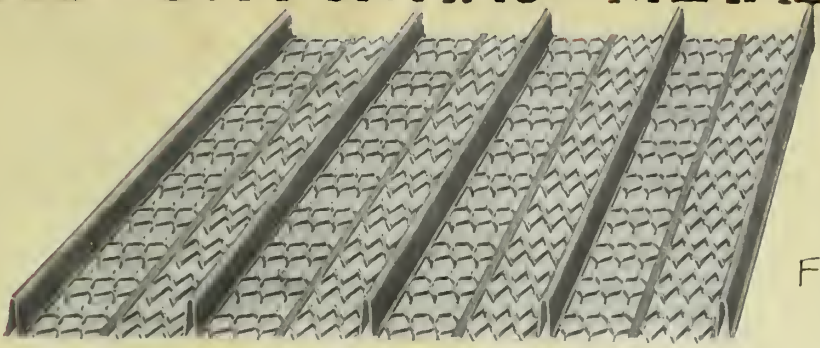


Fig. 6
Corr-Mesh

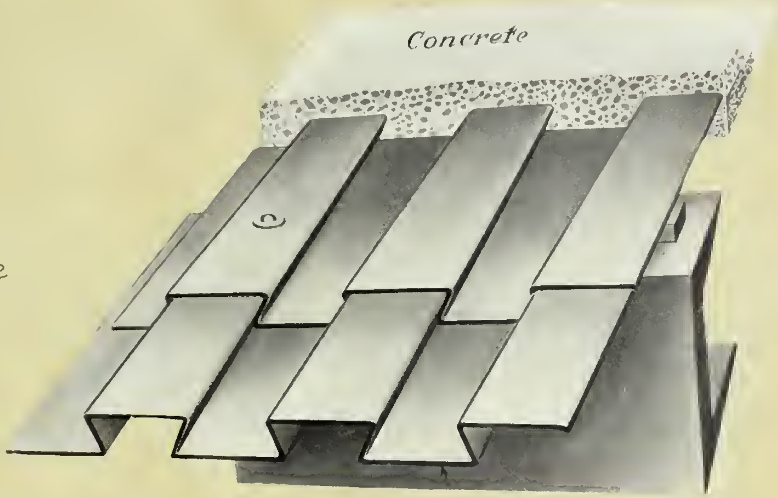


Fig 7
Ferroinclave

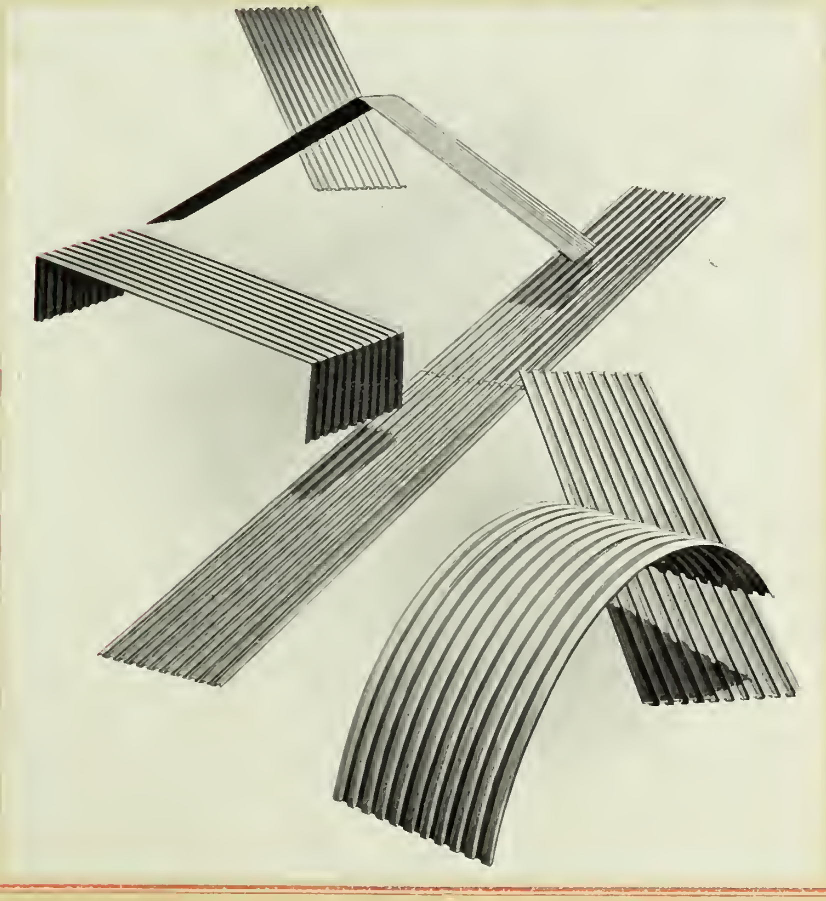


Fig. 8
Usual
Shapes

• SLABS • WITH • FABRIC • REINFORCEMENT •

PLATE XXXVIII

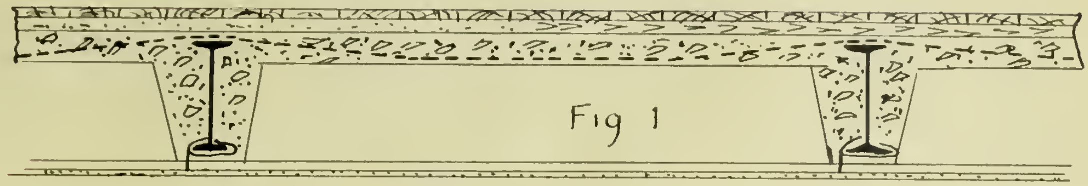


Fig 1

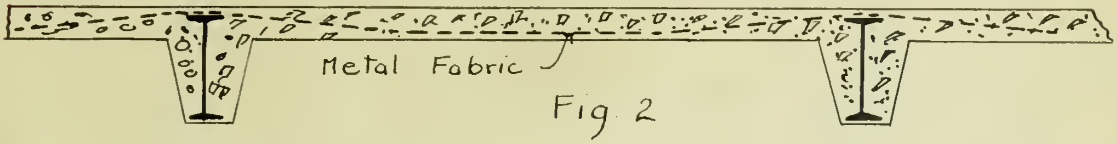


Fig 2

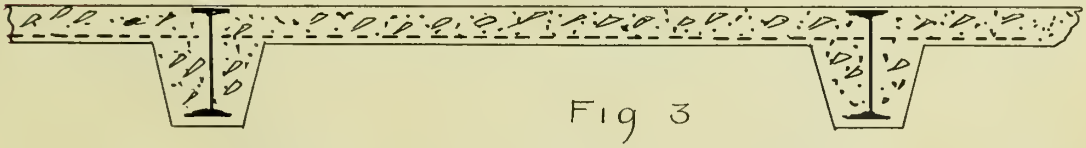


Fig 3

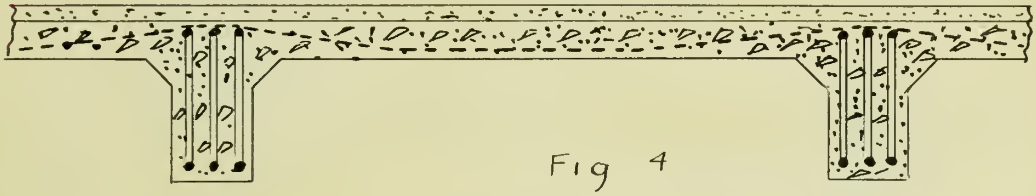


Fig 4

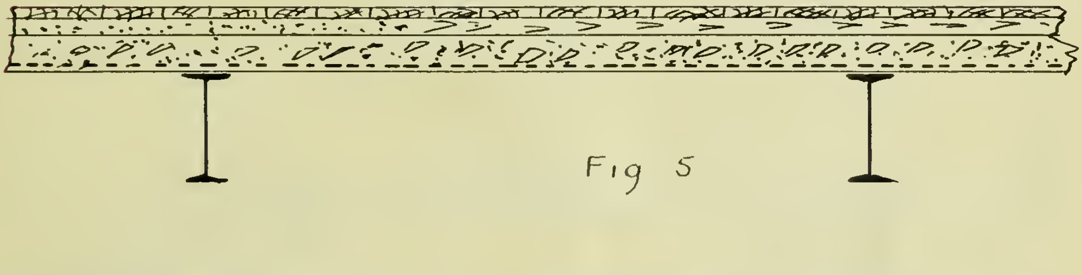


Fig 5

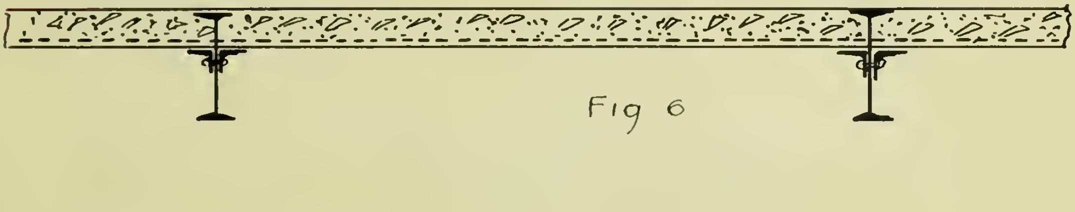


Fig 6

•SLABS•WITH•FABRIC•REINFORCEMENT•

PLATE XXXIX

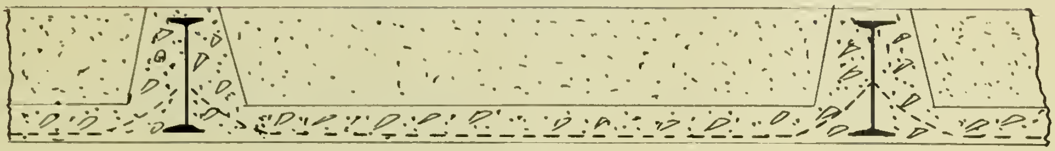


Fig 7

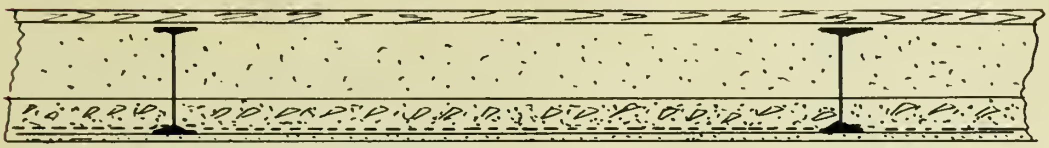


Fig. 8

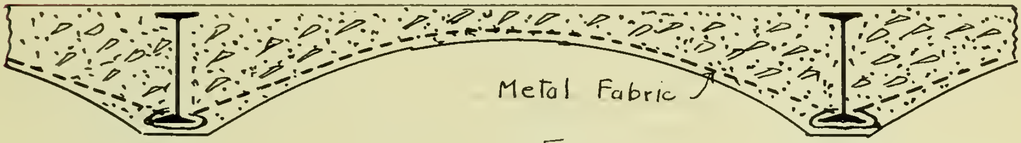


Fig. 9

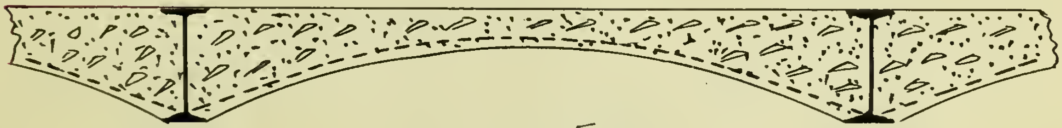


Fig 10

∘TYPES∘OF∘MESH∘REINFORCEMENT∘

PLATE XL

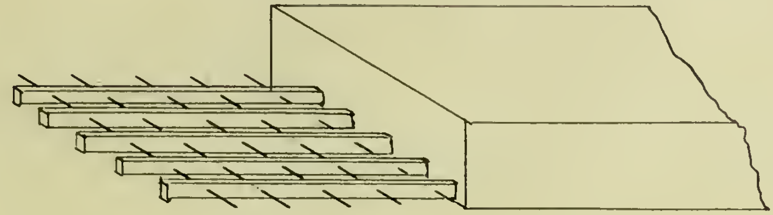


Fig 1 Hyatt

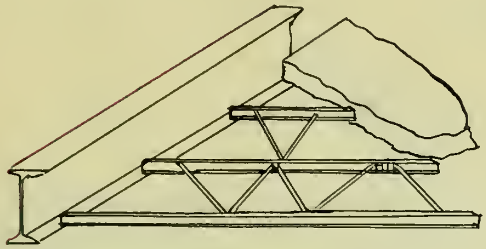


Fig 2 Donath

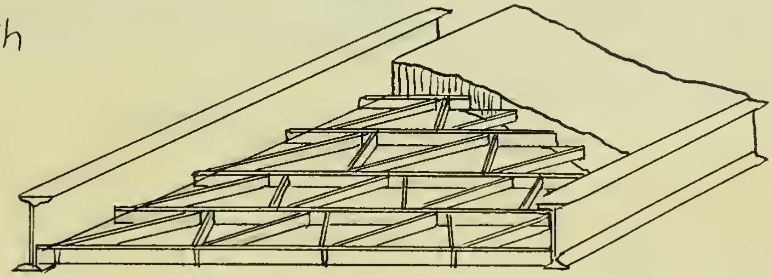


Fig 3 Muller

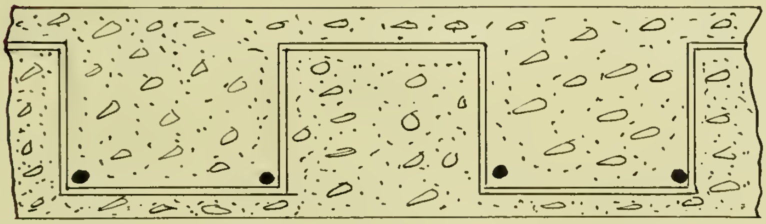
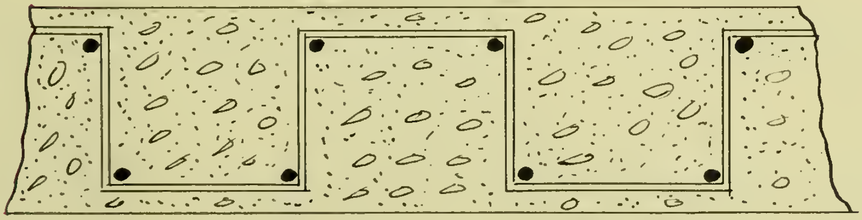


Fig 4 Chaudy



∘ FABRIC ∘ REINFORCEMENT ∘

PLATE XLI

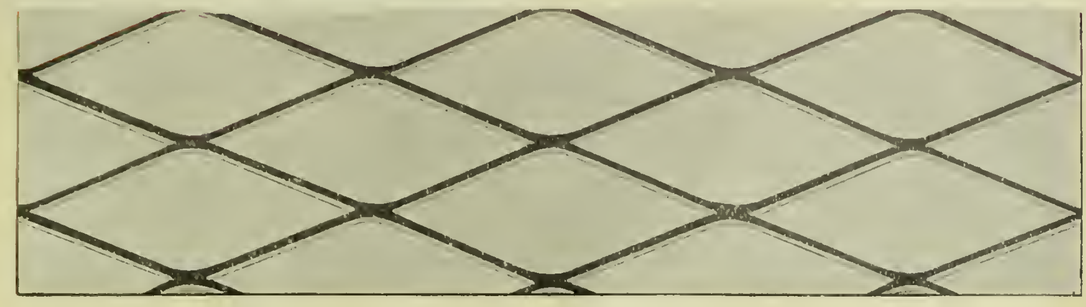
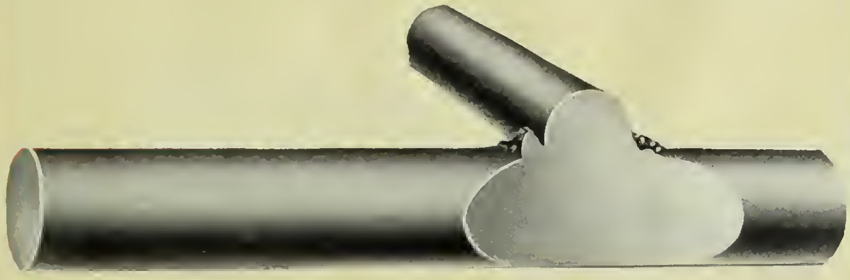


Fig. 1 Expanded Metal
"Steelcrete"



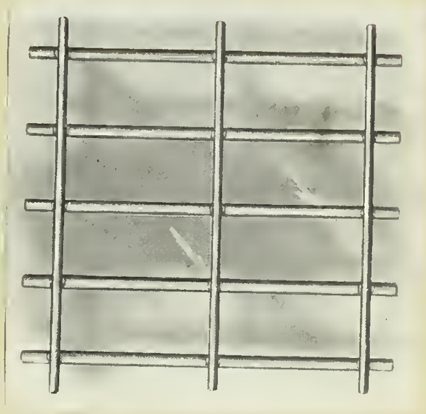


Fig 2 Clinton Welded Wire

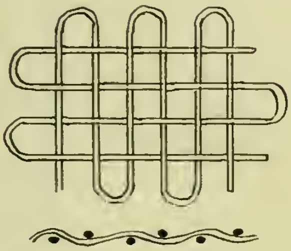
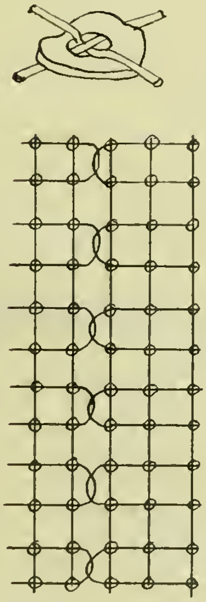


Fig 3

Cottancin Wire



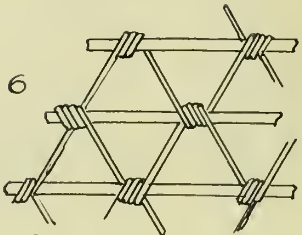


Fig 6 Triangular Mesh

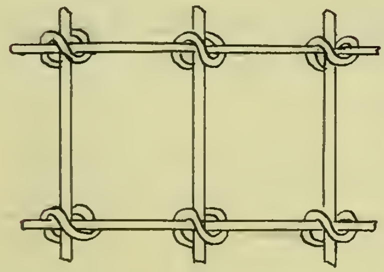


Fig 4 Lockwoven Fabric

Fig. 5 Tie-Locked Fabric

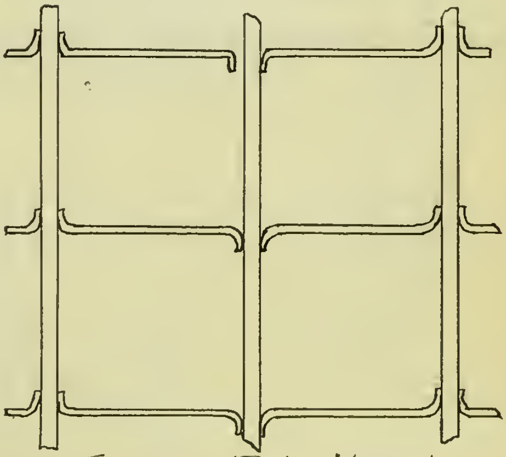


Fig. 7 Rib Metal

◦UNIT◦FRAMES◦

PLATE XLII

Fig 1

American System of Reinforcement

Fig 2 Corrugated Bar Frame

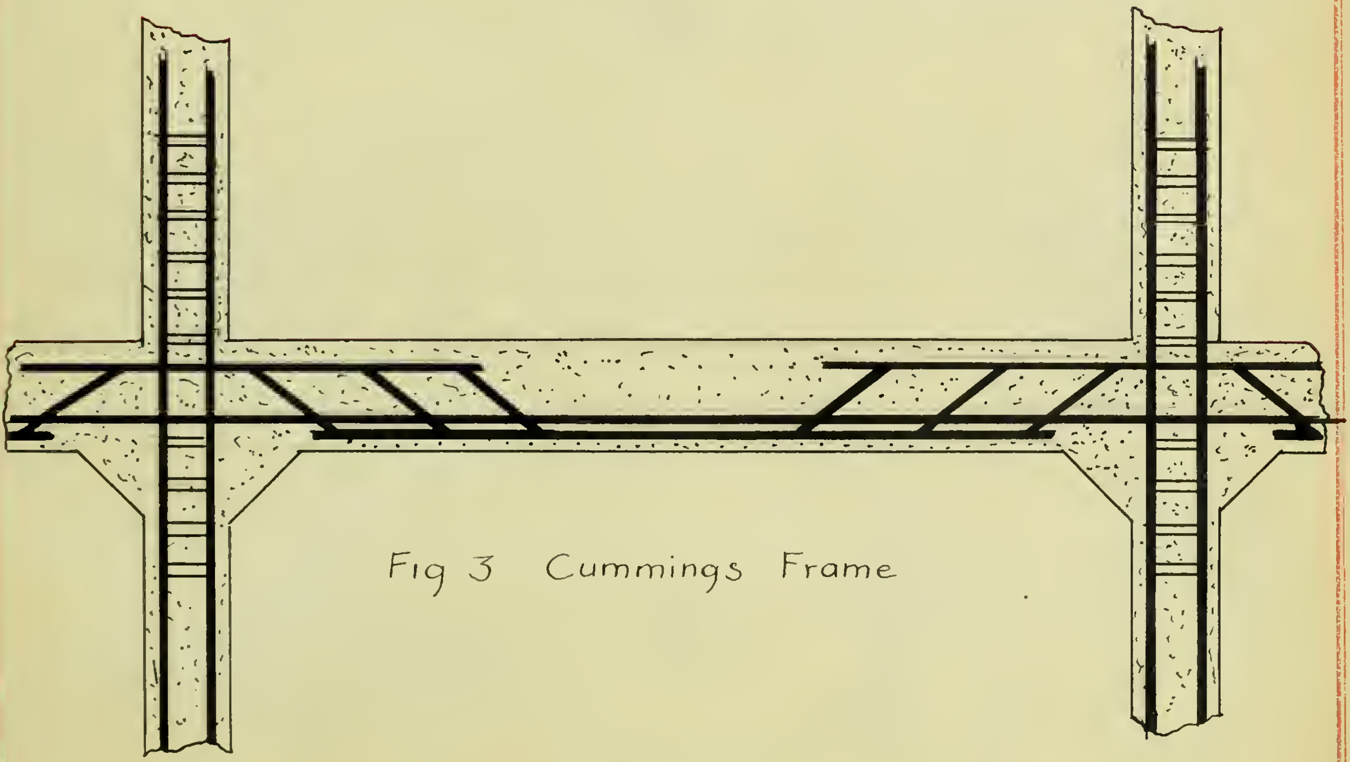


Fig 3 Cummings Frame

◦DEFORMED◦BARS◦

PLATE XLIII

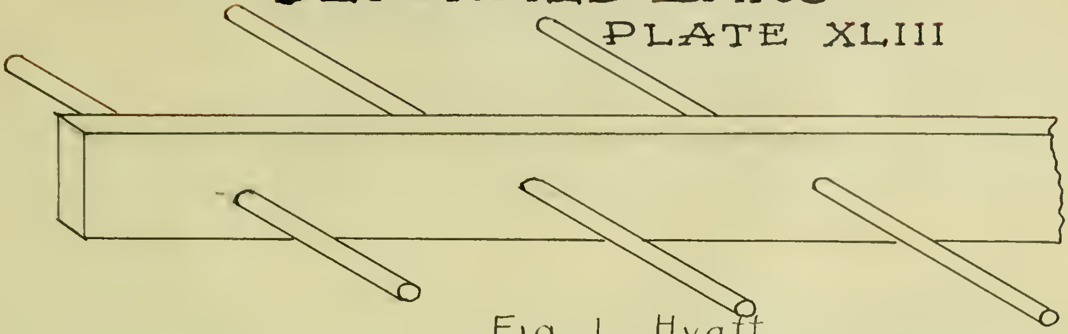


Fig. 1 Hyatt

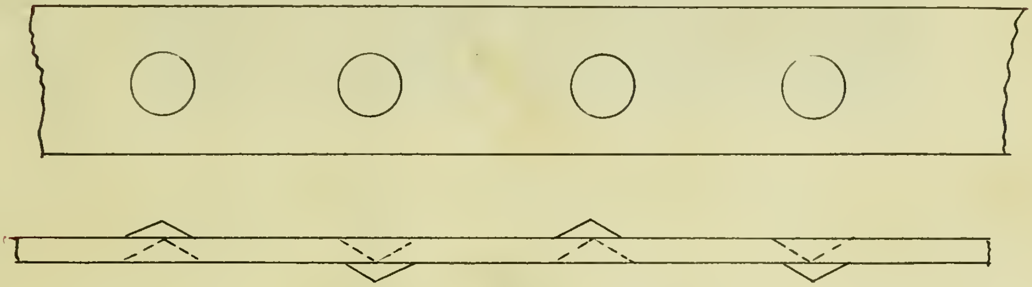


Fig 2 Indented

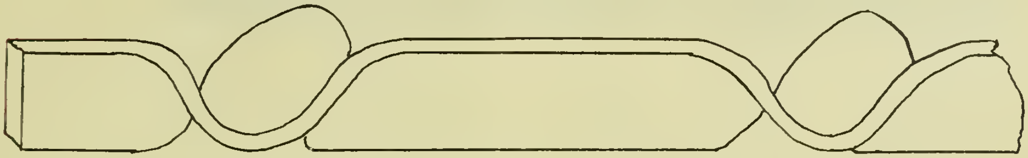


Fig. 3 De Mann

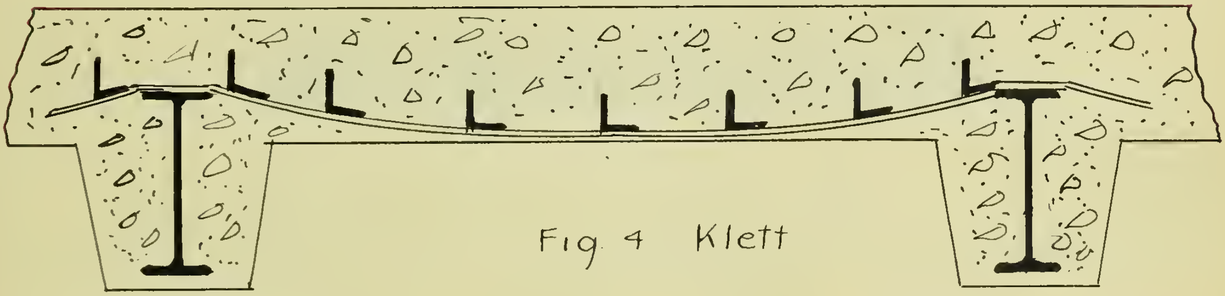


Fig. 4 Klett

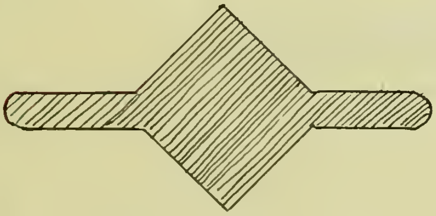
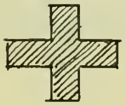


Fig. 5 Kahn



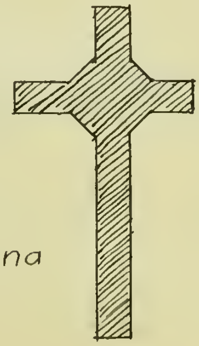


Fig 6 Bonna

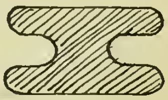


Fig. 7 Golding

Fig 8 Homan

∘DEFORMED∘BARS∘

PLATE XLIV

Fig. 1 Corrugated Bar

Fig. 2 Lug Bar
General Fireproofing Co

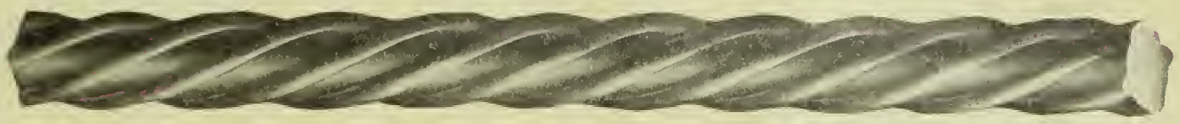
Fig. 3 Thatcher Bar
Concrete Steel Engineering Co

Fig. 4 Diamond Bar
Concrete Steel Engineering Co

∘DEFORMED∘BARS∘

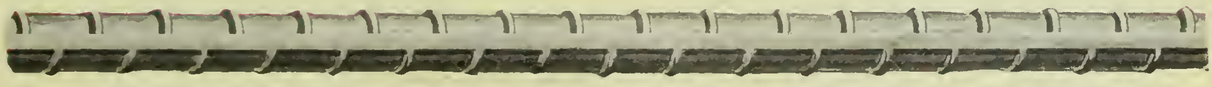
PLATE XLV

Fig. 1 Havemeyer – Round & Square



Bar With Lug

Fig 2 Twisted Ransome Square



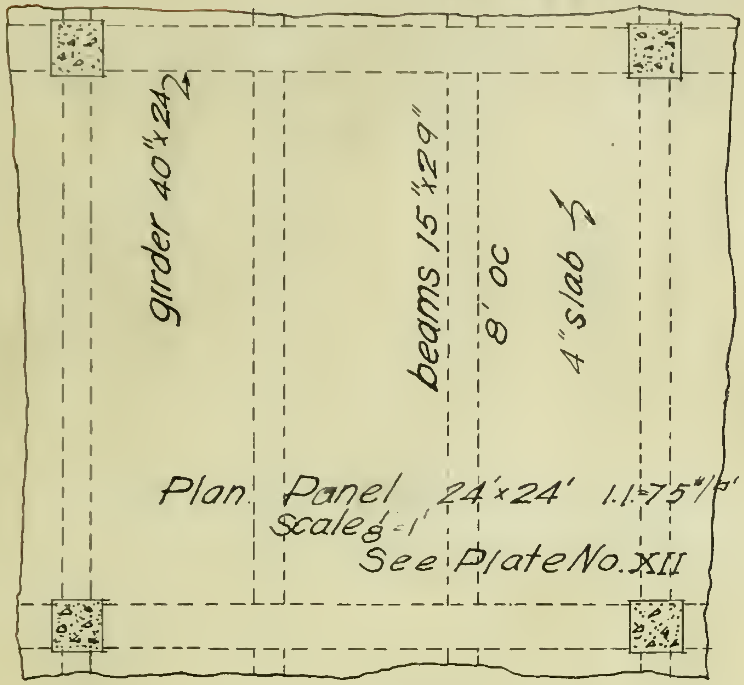
Round

Fig. 3 Corrugated Bars

Square

Fig 4 Rib Bar – Kahn

HENNEBIQUE SYSTEM
PLATE XLVI



$M = \frac{1}{12} w l^2$

Allowable stresses
steel 16000#/□"
concrete 500#/□"

Weight of concrete
150#/cu.ft

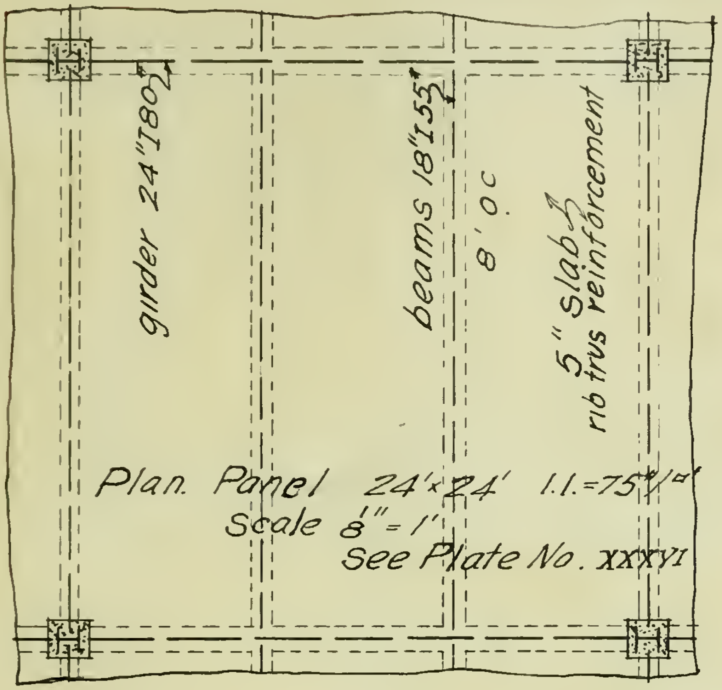
Mixture 1-2-4 n=15

TABLE OF QUANTITES

Span in feet	16 x 16		24 x 24	
Live Load #/sq ft.	75	200	75	200
Thickness of Slab - In	4	5½	4	5½
Depth of Beams - In	22	28	29	34
Depth of girders - In	26	32	40	54
Wt of Slab #	12800	17650	28800	39700
Wt of beams #	5500	8600	24500	40400
Wt of Girders #	5900	9800	21600	29000
Wt. of Panel #	24200	36050	74900	109,100
Dead Load #/sq ft.	94.5	140	130	190
Wt of Steel in Slab #	184	254	430	587
Wt of Steel in Beams #	160	251	605	1041
Wt of Steel in Girders #	156	235	515	697
Wt. Reinforcement #	500	740	1550	2325
Concrete - cu.ft	161	240	500	730
Cost of Concrete	53.70	80.00	166.70	243.00
Cost of Steel	15.00	22.20	46.50	69.80
Cost of Forms - Etc	43.1	48.50	107.80	117.00
Total Cost	111.80	150.70	321.00	429.80
Cost per sq ft.	.44	.59	.56	.75

RIB TRUS SELF CENTERING PLATE

PLATE XLVII



Allowable stresses
steel 16000#/□"
Concrete 500#/□"

Weight of concrete
150#/cu.ft

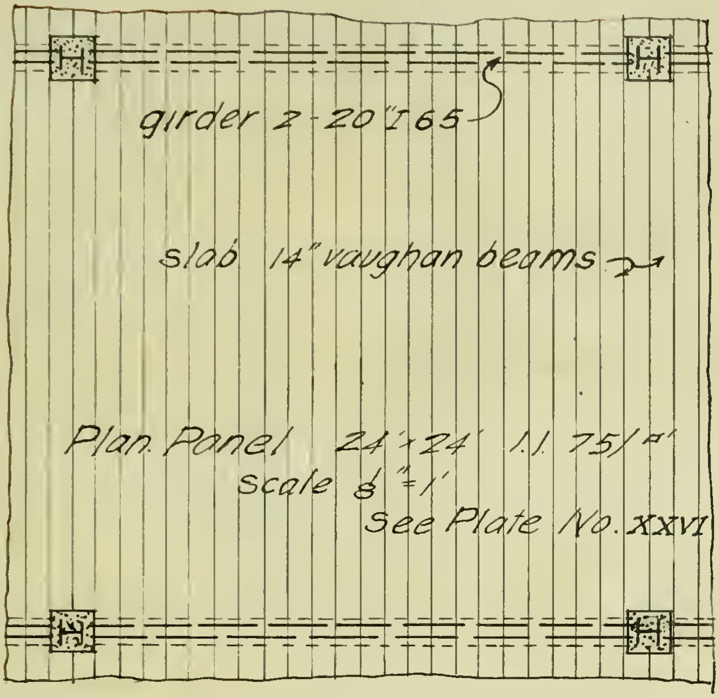
Mixture 1-2-4 n=15

$M = \frac{1}{12}wl^2$ in slabs and
$\frac{1}{8}wl^2$ in beams and girders

TABLE OF QUANTITIES

Span in feet	16 x 16		24 x 24	
Live Load #/sq ft	75	200	75	200
Thickness of Slab In	5	5	5	5½
Depth of Beams In	12 I 16	12 I 16	18 I 22	20 I 24
Depth of Girders In	15 I 19	20 I 24	24 I 28	24 I 28
Wt of Slab #	15850	15850	35700	39400
Wt of Beams #	3710	5510	14760	22000
Wt of Girders #	2750	3940	7920	9750
Wt of Panel #	22310	25300	58380	71150
Dead Load #/sq ft	87.5	99	101	123.5
Steel in Slab #	350	350	290	790
Steel in Beams #	1010	1510	3960	6100
Steel in Girders #	670	1040	1920	3850
Wt of Reinforcement #	350	350	790	790
Wt Structural Steel #	1680	2550	5880	9950
Concrete in Slab #	15850	15850	35700	39400
Concrete in Beams #	2700	4000	10800	15900
Concrete in Girders #	2080	2900	6000	6000
Total Concrete #	20630	22750	52500	61300
Cost of Concrete	45.70	50.50	116.50	136.00
Cost of Reinforcement	10.50	10.50	23.70	23.70
Cost of Structural Steel	50.40	76.50	176.00	298.00
Cost of Total Steel	60.90	87.00	199.70	321.70
Cost of Centering Etc	12.80	12.80	28.80	28.80
Cost per sq ft	.47	.60	.60	.84

VAUGHAN SYSTEM
PLATE XLVIII



Allowable stresses
steel 16000#/□"
concrete 500#/□"

Weight of concrete
150#/cu.ft.

Mixture 1-2-4 $n=15$

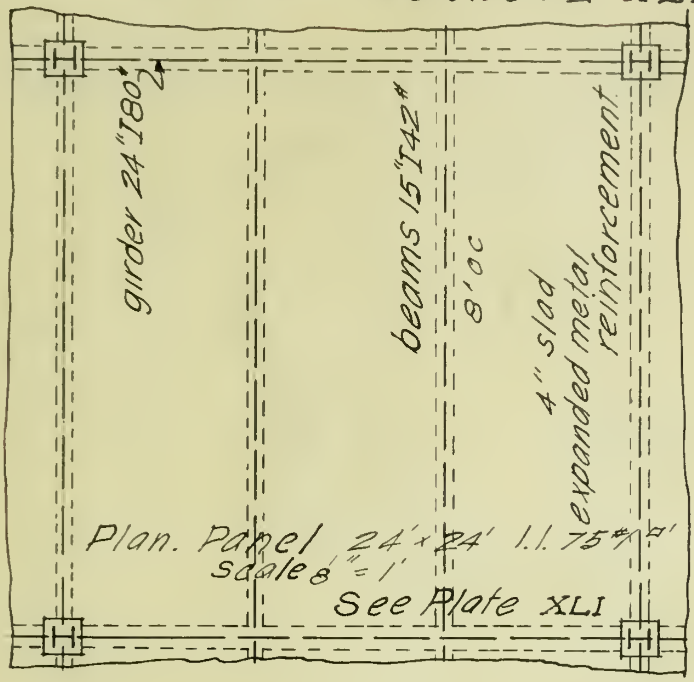
$M = \frac{1}{8} wl^2$

TABLE OF QUANTITIES

Span in feet	16 x 16		24 x 24	
Live Load #/sq ft.	75	200	75	200
Thickness of slab In	9	12	14	20
Depth of Beam In	15 I 19	20 I 24	20 I 24	24 I 28
Wt. of Slab #	15400	17900	46000	75000
Wt. of Beams #	2670	3040	7920	9620
Wt. of Panel #	18170	20940	53920	84620
Dead Load #/sq.ft	71.0	82.0	93.5	147
Steel in Slab #	443	635	1550	2450
Steel in Beams #	670	1040	3120	5520
Total Steel #	1113	1675	4670	7970
Concrete Cu. Ft.	116	133	339	528
Cost of Concrete	38.70	44.30	112.50	176.00
Cost of Reinforcement	13.30	19.05	46.50	73.60
Cost of Structural Steel	20.10	31.20	93.60	165.40
Total Cost of Steel	33.40	50.25	140.10	239.00
Cost of Centering, etc	15.00	18.00	46.00	75.00
Total Cost	87.10	112.55	298.60	490.00
Cost per sq. ft.	.34	.44	.52	.85

EXPANDED - METAL - FLAT - SLAB

PLATE XLIX



Allowable stresses
steel 16000#/□"
concrete 500#/□"

Weight of concrete
150#/cu ft

Mixture 1-2-4 n=15

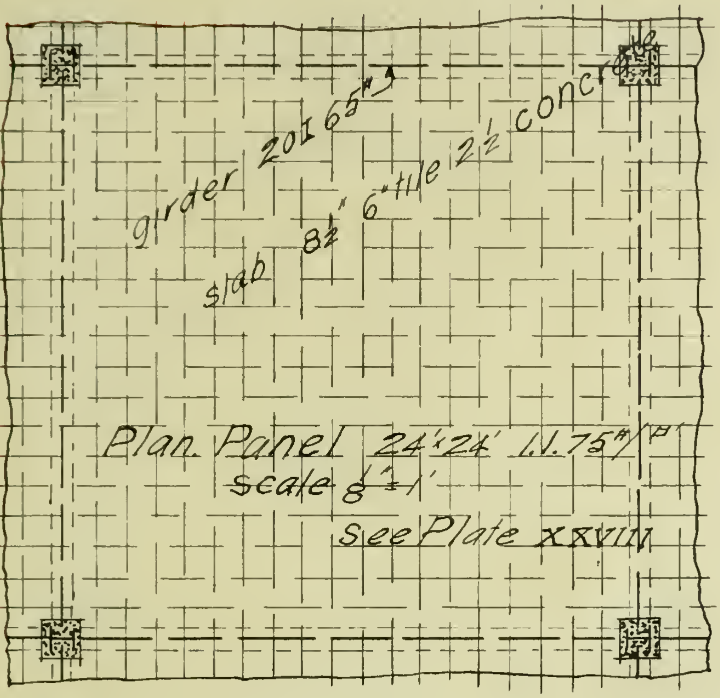
$M = \frac{1}{12} wl^2$ in slab and $\frac{1}{8} wl^2$ in beams and girders

TABLE OF QUANTITIES

Span in feet	16 x 16		24 x 24	
Live Load #/sq ft	75	200	75	200
Thickness of Slab In	4	6	4	6
Depth of Beams In	12 I 16	15 I 19	15 I 19	24 I 28
Depth of Girders In	15 I 19	20 I 24	24 I 28	24 I 28
Wt. of Slab #	12 800	19 200	28 800	43 200
Wt. of Beams #	4 210	5 500	10 220	22 750
Wt. of Girders #	2 740	3 760	7 920	9 840
Wt. of Panel #	19 750	28 460	46 940	75 700
Dead Load #/sq. ft.	770	111.0	815	131
Steel in Slab #	190	238	428	540
Steel in Beams #	1 010	1 340	3 020	5750
Steel in Girders #	670	1 040	1920	3840
Wt. of Reinforcement	190	238	428	540
Wt. Structural Steel	1680	2380	4940	9590
Concrete in Slab #	12 800	19 200	28 800	43 200
Concrete in Beams #	3200	4 160	7 200	17 000
Concrete in Girders #	2 070	2 720	6 000	6 000
Wt. Total Concrete #	18 070	26800	42000	66 200
Cost of Concrete	40.00	59.30	93.00	146.30
Cost of Reinforcement	6.70	7.15	12.90	16.20
Cost Structural Steel	50.20	71.50	148.00	287.50
Cost Total Steel	56.90	78.65	160.90	303.70
Cost of Centering Etc	38.50	40.00	92.5	97.50
Cost per sq. ft.	.53	.69	.60	.95

CORR-TWO-WAY-TILE

PLATE L



Allowable stresses
steel 16000#/□"
concrete 500#/□"

Weight of concrete 150#/cu.ft.

Mixture 1-2-4 n=15

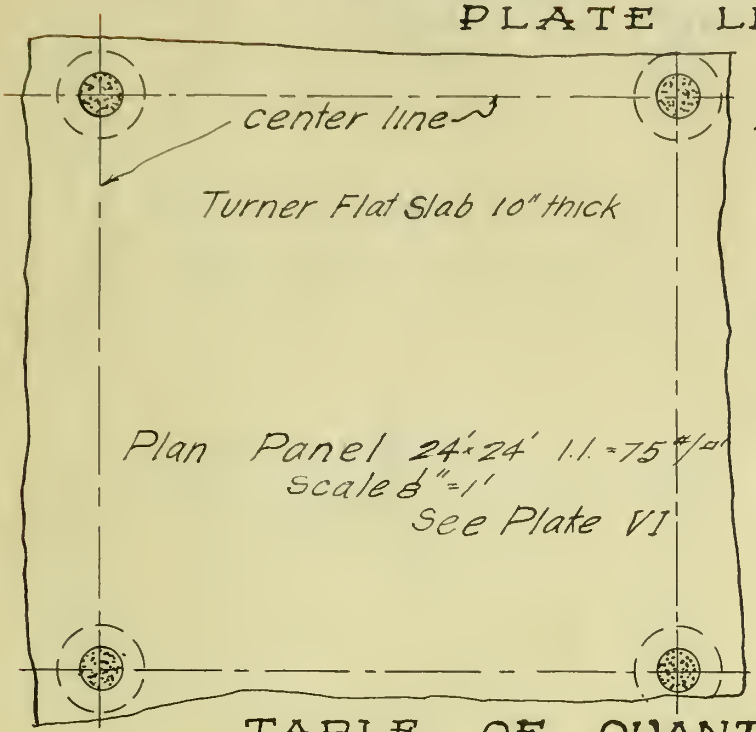
$M = \frac{1}{12} w_1 l^2$ for slab and $\frac{10}{64} w_1 b l^2$ for beams

TABLE OF QUANTITIES

Span in feet	16 x 16		24 x 24	
Live Load #/sq ft	75	200	75	200
Thickness of Slab In	6	8	8½	12
Depth of Beams In	12 I 16	18 I 22	20 I 24	20 I 24
Tile in Slab #	3330	3840	8700	9500
Tile in Beams #	640	960	1920	2880
Wt. of Tile #	3 970	4 800	10 620	12 380
Steel in Slab #	427	590	1 610	1 960
Steel in Beams #	10 106	1 760	3 110	6 250
Wt of Steel #	1 437	2 350	4 710	8 210
Wt. of Concrete #	10 750	13 300	33 500	40 400
Wt of Slab #	14 080	17 140	42 200	49 900
Wt. of Beams #	1 650	2 720	5 030	9 130
Wt of Panel #	15 730	19 860	47 230	59 030
Dead Load #/sq ft	615	77.5	82.0	122.0
Cost of Concrete	23.80	29.50	74.20	89.50
Cost of Tile	48.70	48.70	11,200	112.00
Cost of Reinforcement	12.80	17.70	48.30	58.80
Cost of Structural Steel	31.40	52.90	93.50	187.50
Cost Total Steel	44.20	70.60	141.80	246.30
Cost of Centering Etc.	12.80	12.80	28.80	28.80
Cost per sq. ft.	.50	.71	.62	.82

TURNER - FLAT - SLAB

PLATE LI



Allowable stresses
steel 16000#/□"
concrete 500#/□"

Weight of concrete
150#/cu. ft.

Mixture 1-2-4 $n = 15$

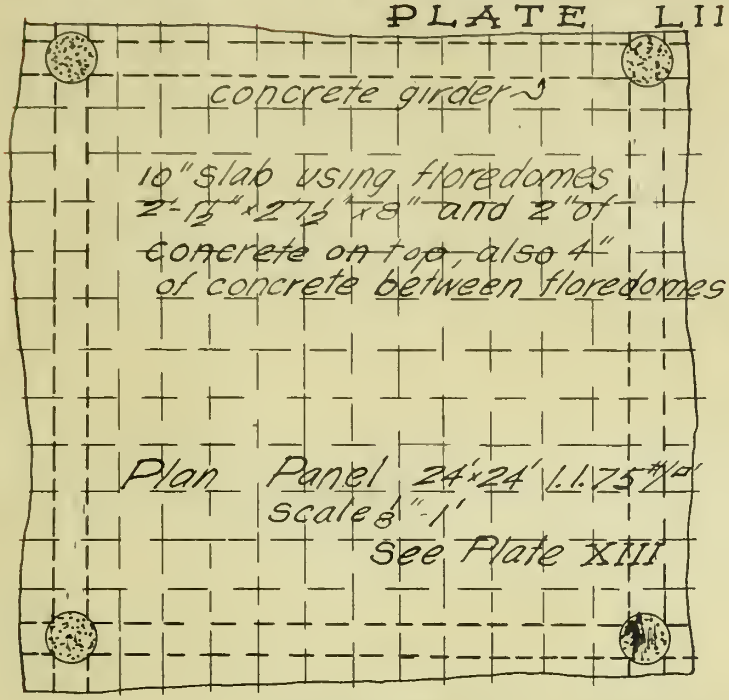
$M = \frac{1}{25} W l^2$

TABLE OF QUANTITIES

Span in feet	16 x 16		24 x 24	
Live Load #/sq. ft	75	200	75	200
Thickness of Slab - In	7	8	10	12
Wt. of Slab #/sq ft	85	100	120	145
Area of Steel □"/sq ft	0.30	0.36	0.50	0.625
Wt of Steel #/sq. ft	1.02	1.22	1.70	2.13
Total Steel #	262	313	980	1230
Dead Load #/sq. ft.	86	100	121	147
Cu Yds Concrete	5.55	6.35	17.60	20.60
Extra Reinforcement #	107	107	308	308
Sq Ft Centering	256	256	576	576
Cost of Concrete	50.00	57.20	158.50	186.00
Cost of Steel	7.86	9.40	29.40	36.90
Cost of Centering	28.20	28.20	63.50	63.50
Cost of Extra Steel	3.21	3.21	9.24	9.24
Total Cost	89.27	98.01	260.64	295.64
Cost per sq. ft.	0.348	0.383	0.453	0.514

KAHN FLOREDOME CONSTRUTION

PLATE LII



Allowable stresses
steel 16000#/□"
concrete 500#/□"

Weight of concrete
150#/cu.ft.

Mixture 1-2-4 $n = 15$

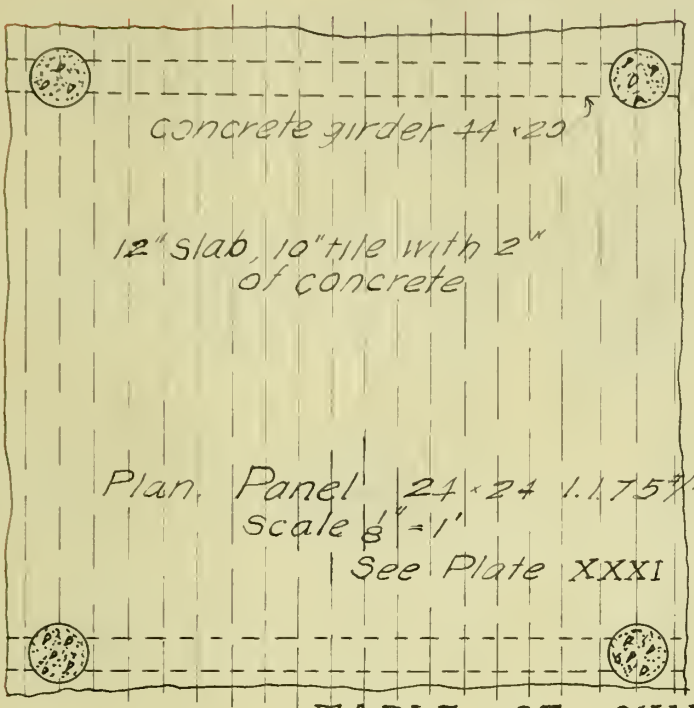
$M = \frac{1}{8} w l^2$

TABLE OF QUANTITIES

Span in Feet	16 x 16		24 x 24	
Live Load #/sq ft	75	200	75	200
Thickness of Slab - In	Tile - Concrete 6+2	8+2	8+2	10+2
Wt of Slab #/sq ft	50	60	60	61
Section of Beams - sq in	300	510	565	1150
Vol. Concrete in Slab - Cu Yds	3.16	3.78	8.54	10.10
Vol. Concrete in Beams - Cu Yds	1.27	1.92	3.5	7.1
Cu Yds Concrete	4.43	5.80	12.04	17.20
Wt Beams #/sq ft	20	23	25	51
Dead Load #/sq ft	70	83	85	122
Area of Steel in Slab □"/sq ft	.41	.79	.79	1.50
Area of Steel in Beams □"/sq ft	1.5	2.5	2.81	5.75
Wt. of Steel in Slab #	356	686	1550	2940
Wt of Steel in Beams #	81.5	136	230	470
Total Steel #	437	822	1780	3410
Sq ft Centering	64	64	144	144
Cost of Concrete	40.00	52.40	108.00	155.00
Cost of Steel	13.10	24.70	53.40	102.30
Cost of Centering	7.05	7.05	15.90	15.90
Cost of Domes & Hyrib	19.90	21.80	49.00	53.50
Total Cost	80.05	105.95	226.30	326.70
Cost per sq ft	.31	.41	.39	.57

KAHN ONE WAY TILE

PLATE LIII



Allowable stresses
steel 16000#/□"
concrete 500#/□"

Weight of concrete
150#/cu ft.

Mixture 1-2-4 $n = 15$

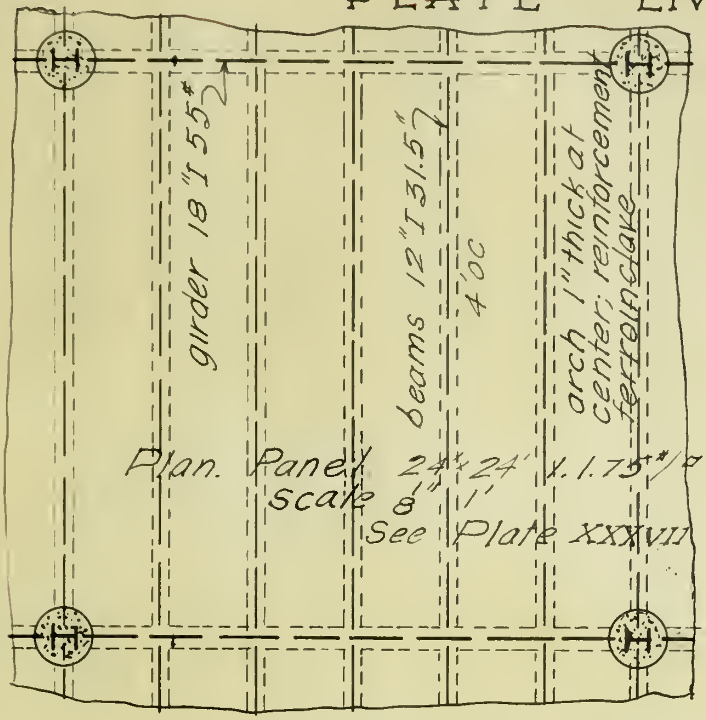
$M = \frac{1}{10} wl^2$

TABLE OF QUANTITIES

Span in feet	16 x 16		24 x 24	
Live Load #/sq.ft	75	200	75	200
Thickness of Slab - In	tile concrete 10 - 1	10 - 2	12 - 2	12 - 6
Wt of Slab #/sq ft	66	78	104	145
Section of Beams - Sq.In	340	550	880	1300
Vol. Concrete in Slab Cu.Yds	2.66	3.4	10.35	16.6
Vol. Concrete in Beams - Cu.Yds	1.4	2.3	5.5	8.0
Cu. Yds. Concrete	4.06	5.7	15.85	24.6
Wt. Beams # per sq ft	22	36	37	59
Dead Load #/sq ft.	88	114	141	204
Area Steel in Slab □"/sq ft.	.41	.79	.79	1.41
Area Steel in Beams □"/sq ft	1.7	2.75	4.40	6.50
Wt. Steel in Slab #	269	516	1160	2080
Wt. Steel in Beams #	92.5	150	360	530
Total Steel #	361.5	666	1520	2610
Sq. Ft. Centering	128	128	256	256
No. of Tile	192	192	360	360
Cost of Concrete	36.60	51.40	143.00	222.00
Cost of Steel	10.80	20.00	45.60	78.40
Cost of Centering	14.10	14.10	28.20	28.20
Cost of Tile	48.00	48.00	110.00	110.00
Total Cost	109.50	133.50	326.80	438.60
Cost per sq. ft.	.43	.52	.57	.76

ARCH WITH SELF CENTERING PLATE

PLATE LIV



Allowable stresses
steel 16000#/□"
concrete 500#/□"

Weight of concrete
150#/cu. ft

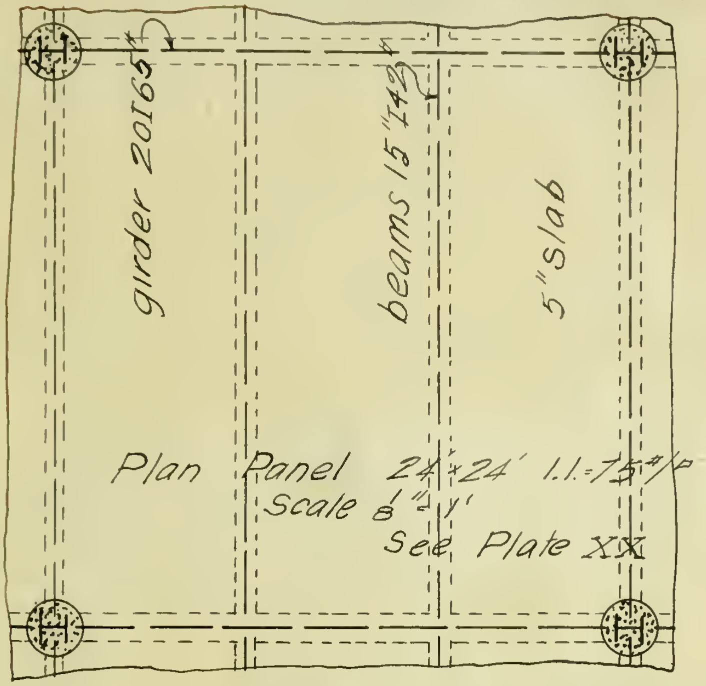
Mixture 1-2-4 n = 15

Arch was taken from companie's table.
$M = \frac{1}{8} W l^2$ in beams and girders

TABLE OF QUANTITIES

Span in feet	16 x 16		24 x 24	
Live Load #/sq. ft.	75	200	75	200
Thickness at Crown In	1	2	1	3
Average Wt. Slab #/sq. ft.	60	112	87	125
Size of Beams	9" I 21	15" I 42	12" I 31.5	18" I 55
Size of Girders	15" I 42	18" I 55	18" I 55	24" I 80
Wt. of Beams #	1000	2020	3020	5300
Wt. of Girders #	670	880	1320	1920
Total Wt. of Steel #(Structural)	1670	2900	4340	7220
Concrete – Cu. Yds	5.0	8.5	15.4	21.0
Wt. of Steel #/sq. ft	6.5	8.5	7.4	12
Dead Load #/sq. ft.	66.5	120.5	94.4	137
Area of Plate sq. ft.	256	256	576	576
Wt. per sq. ft. of Plate #	1.5	1.5	1.5	1.5
Total Wt. Steel Centering	385	385	865	865
Cost of Concrete	45.00	76.50	138.80	189.00
Cost of Steel (Structural)	50.20	87.00	130.00	217.00
Cost of Steel Centering	11.60	11.60	26.00	26.00
Total Cost	106.80	175.10	294.80	432.00
Cost per sq. ft.	.42	.68	.51	.75

ROEBLING SYSTEM
PLATE LV



Allowable stresses
steel 16000#/□"
concrete 500#/□"

Weight of concrete
150#/cu ft.

Mixture 1-2-4 n=15

$M = \frac{1}{8} w l^2$

TABLE OF QUANTITIES

Span in feet	16 x 16		24 x 24	
Live Load #/sq ft.	75	200	75	200
Thickness of Slab – In.	5	7	5	7
Wt. of Slab #/sq ft.	60	85	60	85
Size of Beams	12 I 31.5	12 I 40	15 I 42	18 I 55
Size of Girders	15 I 42	18 I 55	20 I 65	2-20 I 65
Wt. of Beams #	1000	1280	3000	3950
Wt. of Girders #	670	880	1040	2080
Fireproofing – Cu. yds.	1.04	1.2	2.67	2.96
Total Volume Concrete – Cu. yds	4.96	6.76	11.57	15.66
Wt. of Concrete #/sq ft	79	104	81.8	110
Wt. of Steel #/sq ft	6.5	8.4	7.2	10
Dead Load #/sq ft.	85.5	112.4	89	120
Wt. Steel per sq. ft. Slab	.825	1.7	.825	1.7
Wt. of Reinforcement #	211	435	475	980
Sq ft Centering	336	344	780	792
Cost of Concrete	44.60	60.90	104.00	141.00
Cost of Reinforcement	6.32	13.10	14.25	29.40
Cost of Structural Steel	50.20	64.80	121.20	181.00
Cost of Centering	37.00	37.90	86.00	87.20
Total Cost	138.12	176.70	325.45	438.60
Cost per sq. ft.	.54	.69	.56	.76

COMPARATIVE TABLE

PLATE LVI

S = *wt. of steel per sq ft*

C = *wt. of concrete per sq. ft.*

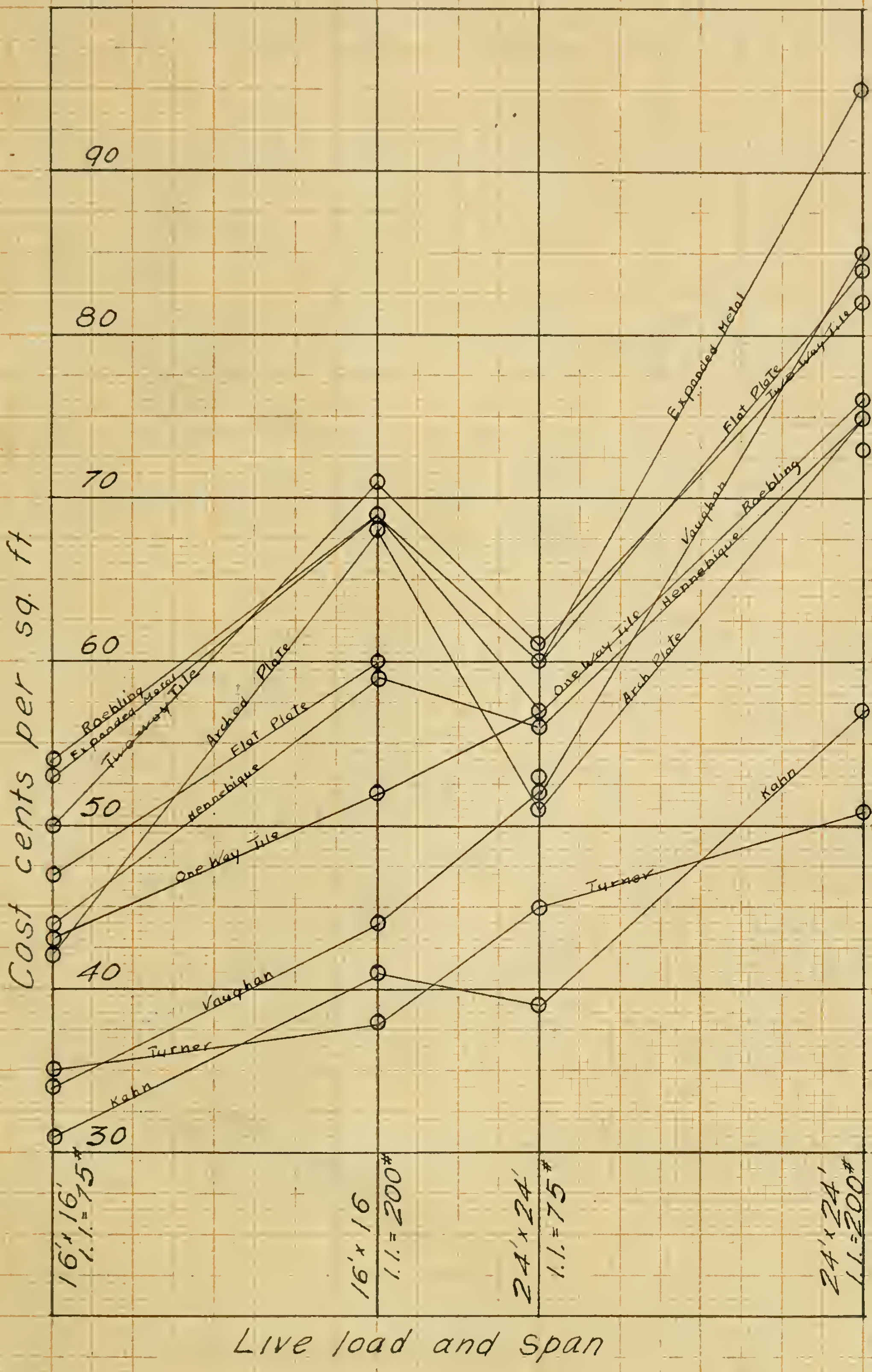
DL = *dead load per sq. ft.*

Cost = *total cost per sq. ft.*

		16 x 16								24 x 24							
		75				200				75				200			
		C	S	DL	Cost	C	S	DL	Cost	C	S	DL	Cost	C	S	DL	Cost
1. Turner	C	85				99				119				145			
	S		1				12				17				21		
	DL			86				100				121				147	
	Cost				35				38				45				51
2. Hennebique	C	93				137				127				186			
	S		2				3				2.7				4		
	DL			95				140				130				140	
	Cost				44				59				56				75
3. Kahn	C	68				80				82				116			
	S		1.7				3.2				3.1				5.9		
	DL			70				83				85				122	
	Cost				31				41				39				57
4. Roebling	C	60				85				60				85			
	S		25				27				29				35		
	DL			85				112				89				120	
	Cost				54				69				57				76
5. Vaughan	C	67				76				85				133			
	S		4.3				6.5				8.1				13.8		
	DL			71				82				93				147	
	Cost				34				44				52				85
6. One Way Tile	C	42				54				80				117			
	S		1.4				2.9				2.6				4.5		
	DL			88				114				141				204	
	Cost				43				52				57				76
7. Two Way Tile	C	47				52				58				70			
	S		.6				1				.9				1.4		
	DL			61				77				82				122	
	Cost				50				71				62				82
8. Flat Plate	C	80				89				91				107			
	S		7				10				10				16		
	DL			87				99				101				123	
	Cost				47				60				60				84
9. Arched Plate	C	58				108				85				123			
	S		8				12				9				14		
	DL			66				120				94				137	
	Cost				42				68				51				75
10. Expanded Metal	C	72				105				73				115			
	S		5				6				8				16		
	DL			77				111				81				131	
	Cost				53				69				60				95

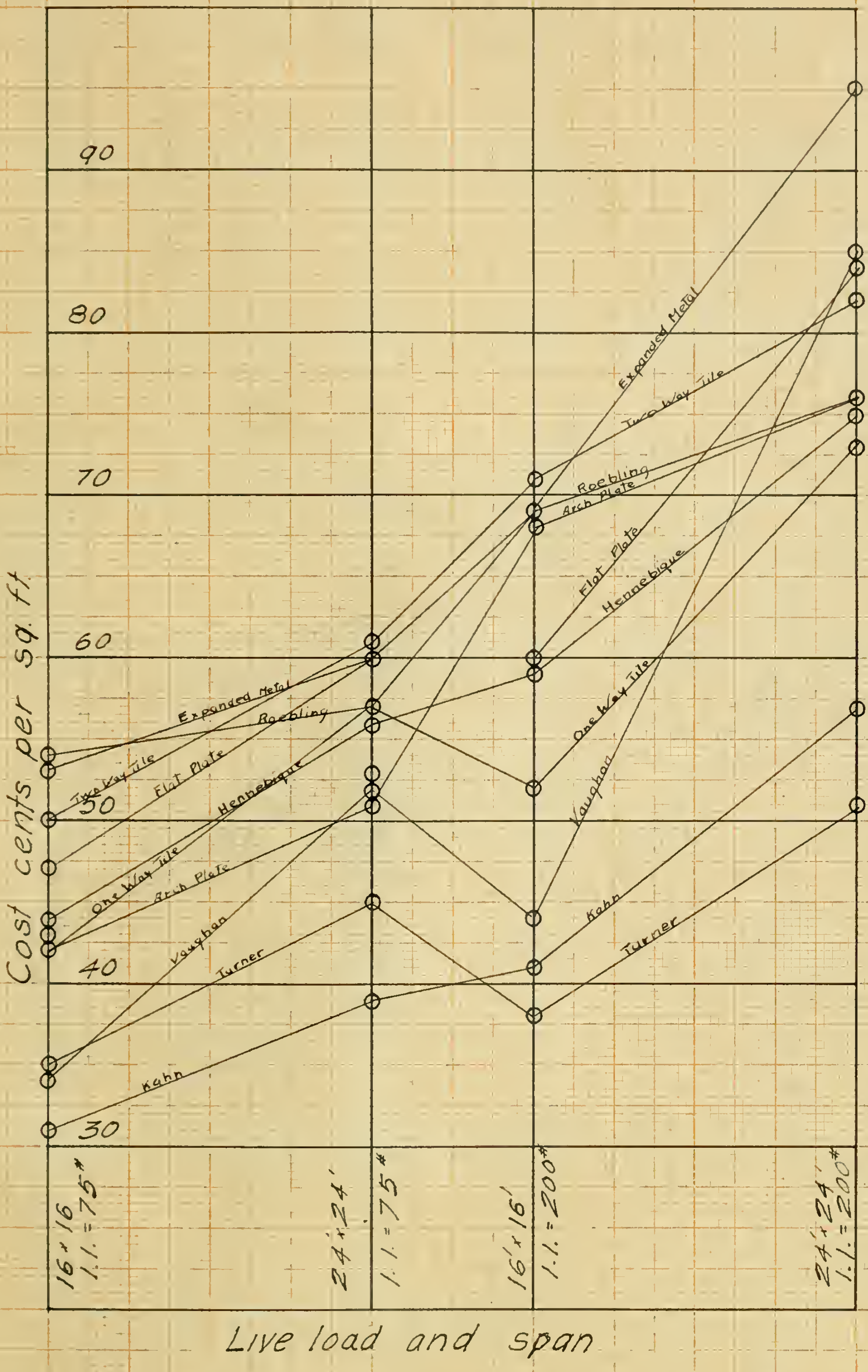
VARIATION OF COST WITH LOAD

PLATE LVII



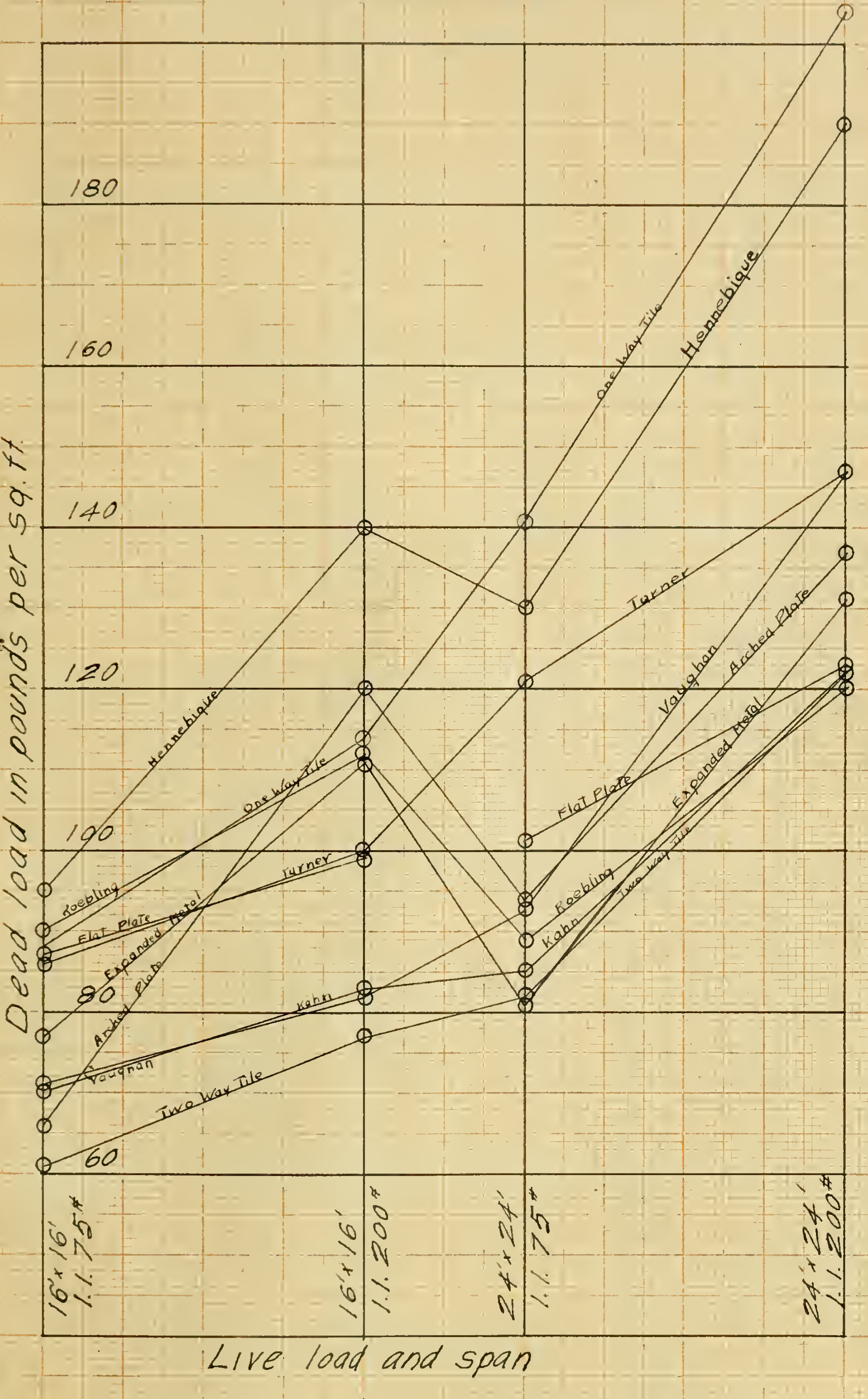
VARIATION OF COST WITH SPAN

PLATE LVIII



VARIATION OF DEAD LOAD WITH LOAD

PLATE LIX



VARIATION OF DEAD LOAD WITH SPAN

PLATE LX